

The AMSAT[®] Journal

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Volume 23, No. 5

September/October 2000

CONTENTS

Phase 3D Prepares for Launch.....1
By Lou McFadin, W5DID

**Testing the International Space
Station's Amateur Radio
Equipment - Russian Style.....2**
By Lou McFadin, W5DID

Apogee View.....3
By Keith Baker, KB1SF

Infrared Laser on Phase 3D.....7
*By Karl Meinzer, DJ4ZC; Dante
Bauer, DH2FHB; Dick Jansson,
WD4FAB; and Herman Günther*

**Phase 3D New Bands, Part 2:
Antennas and Transmitting.....9**
By Ed Krome, K9EK

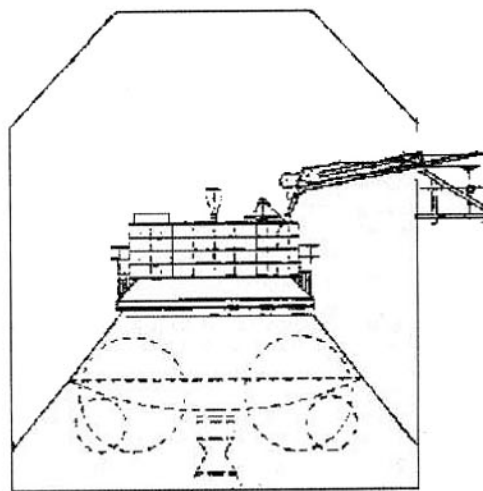
**Putting Together a L/S Band
Antenna System for the Phase 3D
Satellite.....13**
*By Jim Koehler, VE5FP and Eric
Rawson, KN6KC*

**Spectrum Analyzer 0...1750 MHz:
Part 2.....20**
By Matjav Vidmar, S53MV

**2000 AMSAT Field Day
Competition Results25**
By Andy MacAllister, W5ACM

AMSAT Journal Telemetry.....29

Satellite Orbital Elements.....31
By Ray Hoad, WA5QGD



An artist's interpretation of the final human touches on Phase 3D. About two weeks before launch, an AMSAT team member will lie down on a *diving-board like* platform which extends through a hatch in to the adapter cone. On top of Phase 3D is a shorting safe plug which prevents the engine from firing by accident. The safe plug has to be removed and replaced with an arm plug before launch. Replacing the plug also connects an indicator line which verifies that the correct plug is installed for flight.

Phase 3D Prepares For Launch

Lou McFadin, W5DID, Phase 3D Integration Team

As we go to press, Phase 3D sits in French Guiana almost ready for launch. Our baby's scheduled to fly on Ariane 507 around the end of October. To avoid any chance of shipping damage the solar arrays, main engine, and other delicate components were removed from the spacecraft and shipped in their own protective containers.

Preparation of the final ground support equipment has continued at the Phase 3D Integration Laboratory in Orlando, Florida. One of the more unusual tasks was to assemble a 131-foot (40 meter) cable to charge the spacecraft's batteries in French Guiana. It was an extremely

[continued on page 4]

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850 Sligo Avenue, Ste 600
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Testing the International Space Station's Amateur Radio Equipment – Russian Style

Lou McFadin, W5DID

When you work on an International Space Station (ISS), much of the work involves international partners. The early living quarters aboard ISS are in the Russian-built Service Module, so it shouldn't be surprising that that's where the ham shack will be located. While most of the ham radio equipment was built by AMSAT-NA, it's got to hook up to Russian power and RF connectors. So Carolyn Conley, KD5JSO and myself visited Moscow for a week in July with some of the flight equipment to have it certified by the Russian engineers. The Functional Cargo Block (FGB) was built by the Khrunichev Space Center. NPO Energia was the manufacturer of the Service Module and responsible for the integration of both Russian spacecraft.

The key purpose for the trip was to test the packet module, certify the power cables and verify how the antenna cable would connect to the FGB's connectors. Many Russian cables and connectors are similar to their Western counterparts – but not identical. So one end of the power cable has a Russian power connector, the other end connects to the U.S.-built ham radio rig. The antenna cable has a Russian RF connector on one end and a BNC cable on the opposite end. In addition we carried a flight packet module.

The ARISS team has been working on a set of four external antennas for the Service Module, but they won't be ready for flight until next year. The ARISS team obtained permission to use the Sirius telemetry antenna on the FGB as a temporary ham radio antenna for the space station. The Sirius antenna was used during the FGB's launch for telemetry but is no longer needed. Fortunately its antenna cable is easily accessible from within the crew cabin.

On July 24th we went to the Energia offices in Korelov to meet Sergei Samburov RV3DR, and his boss, ex-cosmonaut Alexandr Alexandrov. After preliminary meetings we met with the Russian spacewalk experts. We discussed how to package our three 2 meter / 70 cm antennas and 10 meter and L/S antenna, and whether to carry them on shuttle or on a Russian Progress freighter. The antennas are fairly bulky, and these issues remain to be resolved in the future. It's anticipated that the antennas won't be installed until the second Expedition crew is onboard at the earliest.

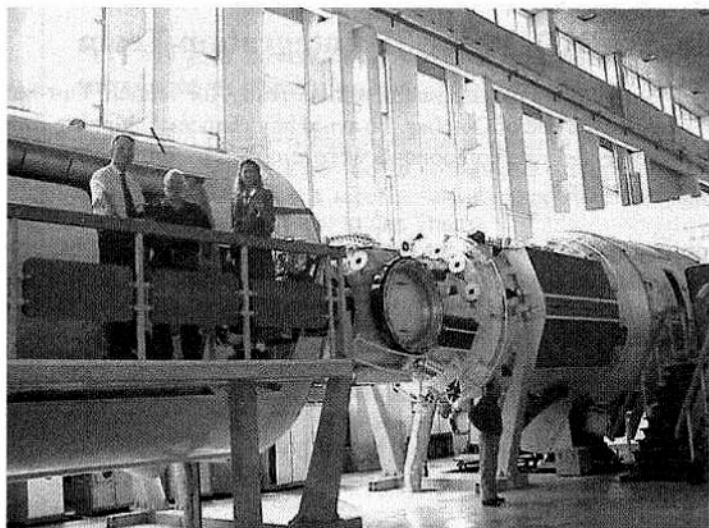
The Russian Service Module is very similar to the *Mir's* core module. So it isn't surprising that the permanent home for the ARISS setup will be in the same location in the Service Module. In the U.S. the normal aerospace practice is to build one flight unit, and several simulators with differing levels of fidelity, depending on the purpose. In contrast Russian aerospace manufacturers usually build two almost identical pieces – one for flight and one for ground testing. So when we went inside the mockups it really felt like we were inside a real spacecraft.

Sergei gave us a tour and showed us where everything went. We hooked up the packet module with a set of dummy loads to the Service Module to verify that the current surges didn't exceed acceptable limits. Later in the week we visited the Khrunichev space center and performed the same tests on the FGB. On orbit one of the crew members will have to open up a hinged FGB panel, disconnect the existing antenna cable, replace it with our cable, thread the antenna through a small crack in a panel, and reassemble it. A nut will have to be unscrewed from a grounding lug for our ground wire. It sounds simple, and on the ground it is. But everything in space takes longer when you have to worry about parts floating away. The key to a successful task in space is careful planning ahead.

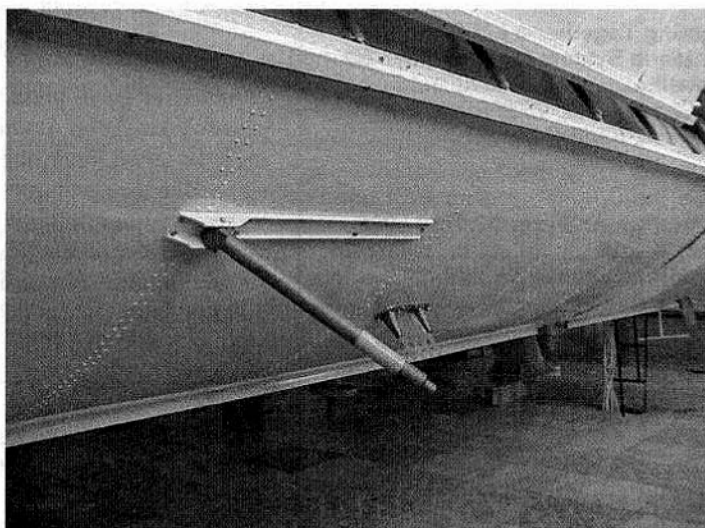
In addition we checked our out RF cables with Khrunichev's test equipment. The testing setup should look very familiar to any ham with access to an RF laboratory, but all of the test equipment was Russian made. The Sirius antenna was designed to operate at 147 MHz, so we expected the SWR to be slightly off for the 144-146 MHz. range. At 144 MHz. the Sirius antenna has an SWR of about 1.4:1. At 146 MHz. the SWR is about 1.2:1. Not fantastic, but certainly acceptable for a temporary antenna.

We discussed potential EMI issues with the Khrunichev folks and they were satisfied that our equipment wouldn't interfere with any of the space station's critical systems. On Friday we visited the Gagarin Cosmonaut Training Center (GCTC). This is where cosmonauts have trained to fly in space since the beginning of the space age. We viewed another set of mockups of both vehicles and discussed training requirements with the folks who will train the space station crewmembers. In addition we gave our Russian counterparts the packet module settings and other information needed to configure the packet module inflight.

The trip was an incredible success in terms of accomplishing all of our objectives. Most important both Energia and Khrunichev accepted the ARISS equipment for flight, and operation within the Russian segment of the International Space Station. In addition we now have many friends within the Russian aerospace industry, an invaluable asset for future space-based Amateur Radio activities. The initial ARISS hardware will fly on the STS-106 mission in early September with many of the ARISS team members watching. The Expedition 1 crew of Bill Shepherd, KDSGSL, Sergei Krikalev, USMIR, and Yuri Gidzenko (call sign TBD) and at press time is scheduled for launch at the end of October. And if all goes as planned, some time in November they'll open up the FGB panel to access the antenna cable and ground connector and hook up the first Amateur Radio rig aboard the International Space Station. (See more ISS photos on page 6) ■



A Russian Official, Lou McFadin, W5DID, and Carolyn Conley, KD5JSO in front of the FGB mockup at the Gagarin Cosmonaut Training Center in Moscow. Note the Sirius antenna above W5DID's head. The Service Module mockup is on the right side of the photo.



The Sirius telemetry antenna in its deployed operational position. When undeployed, it will be stowed in a position parallel to the module.



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Suite 600, Silver Spring, MD 20910-4703.

The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly
(Jan, Mar, May, Jul, Sep, Nov) by AMSAT-NA, 850 Sligo Avenue,
Suite 600, Silver Spring, MD 20910-4703. Telephone:
301-589-6062, fax: 301-608-3410. Periodicals postage paid at
Silver Spring, MD, and additional mailing offices. Postmaster, send
address changes to The AMSAT Journal, 850 Sligo Avenue, Suite
600, Silver Spring, MD 20910-4703.

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and efforts to produce The AMSAT Journal.

Transitions

If all goes according to plan, this edition of the AMSAT Journal will be hitting your mailboxes just prior to our 2000 AMSAT-NA Annual Meeting and Space Symposium. This meeting continues a proud tradition that AMSAT started in the early 1980s to provide an annual forum for amateur satellite enthusiasts to gather and share their ideas among like-minded friends and colleagues. What's more, those of you who will be joining us in Maine will soon discover (if you haven't already) that Northern New England is a beautiful setting for a meeting this time of year.

It is particularly fitting for me personally to be meeting in my own native surroundings as it will mark my last AMSAT Annual Meeting while serving as a senior elected official of AMSAT-North America. After a lot of serious thought, it is with a great deal of regret that I inform you all of my decision not to seek re-election as President of AMSAT-NA when my current term of office expires in October.

As many of you well know, I have been actively involved in the AMSAT-NA leadership for nearly 6 years now, having assumed the Executive Vice Presidency of the organization in October, 1994 soon after my "retirement" from the US Air Force and my election as a member of the AMSAT-NA Board of Directors in October of 1994. During this time I have always tried to give AMSAT my very best efforts, attempting to faithfully serve you to the best of my abilities and as my available time and schedule have permitted.

However, within the past few years, I have also been actively expanding my own personal corporate consulting and training enterprises. In addition, my family and I have started (and are now in the process of greatly expanding) another, far more labor-intensive (but nonetheless "fun") family business that is doing wonders to further strengthen our already close family ties. As you can well imagine, each of these activities must, of necessity, come before any volunteer work that I may undertake. I am still in my "mid-career" professionally and the future financial security of my family must remain a top priority. Unfortunately, it has also become increasingly apparent to me that while trying

my very best to juggle all of these activities and responsibilities, the time I often have left to devote to AMSAT and its "full time" Presidential duties has now dwindled significantly.

As many of you know, I have also been a firm believer in the notion that leaders of volunteer organizations should always endeavor to rise from the ranks to serve in leadership roles, but then should also strive to eventually return to those same ranks to give others a chance to serve. This approach helps keep the organization fresh and alive, not to mention greatly expanding the pool of leadership talent available within the group. It also keeps a wealth of new and innovative ideas continually flowing upwards from the membership to the leadership.

Needless to say, it has been particularly gratifying for me to serve as your Executive Vice President and then later, as your President, when we marked a series of major milestones in our ongoing Phase 3D project. The latest of these milestones occurred in January when Phase 3D arrived safely at the launch site in Kourou, French Guyana to await a ride to orbit on an Arianespace Ariane 5 launch vehicle. What's more, if all is going as planned (and that is still a BIG "if" as I write these words!) many of our Phase 3D experimenters should have been putting in many long hours at the launch site to (finally!!) prepare the satellite for launch.

So, as I depart from my six years in office as one of your senior executives, and like those that have followed before me, my only hope is that in some small way I have left the organization just a little bit better off than when I found it. However, what is even more gratifying to me is that I am departing the Presidency with the firm knowledge that our organization will be in the hands of some of the very best people I've ever had the pleasure to have known. In that sense, my friends, we are all most fortunate.

To each of you, I extend a very personal and heartfelt "thanks!" for your strong support and best wishes during my time in office. It has been an honor and a pleasure to have served with each of you.

73,

Keith Baker, KB1SF

[continued from page 1] hand-intensive task to slip the cables through the protective nylon sleeve.

Since Arianespace has a very busy launch schedule for the remainder of the year, they had the option of performing the filling of Phase 3D's fuel tanks in the Ariane 4 Final Assembly Building instead of S3A. Because of this building's size, we will need a 40M long cable running to the control room.

Several Phase 3D team members from Germany, the United States, Belgium, Czech Republic, Finland and other countries involved will travel to the launch site for the final integration. Peter Guelzow, DB2OS is Satellite Project Manager and Mission Director since Karl Meinzer, DJ4ZC will not be able to travel to Kourou because of sudden health problems. Chuck Green, N0ADI is Deputy Project Manager. The first task, of course, will be to verify that everything's there and undamaged. Much of the early tasks will look like packaging the pieces for shipment in reverse.

Phase 3D rides into orbit inside the Specific Bearing Structure (SBS). The SBS is a tuna can-shaped open cylinder that mates to the Ariane 5 launch vehicle. The SBS shipping box also includes all of the support equipment for the launch - everything from computers and tools to clean room garments. We'll take everything out of the SBS box and give the SBS to Arianespace so they can perform alignment checks.

The next step is to reassemble the rotisserie. This is the rotating fixture where Phase 3D spent most of its time while it was assembled and tested at the Integration Laboratory in Florida. Arianespace will give members of

the Phase 3D team training to operate its cranes which will be used to put Phase 3D on the rotisserie. The plastic *baggie* that protected Phase 3D during shipping will be removed at this point.

While all of that's happening other members of the team will put together the solar array simulator, set up ground support computers, and the various umbilicals which go from the spacecraft to the test equipment.

The flight side panels and bottom panels will be removed from the spacecraft to permit access. The main bipropellant engine will be reinstalled at this point.

Next a last-second but expected and planned addition will be added to the spacecraft. Besides the *normal* RF transmitters from 2 meters to 24 GHz. Phase 3D will include a 900 nanometer transmitter. That's in the infrared portion of the spectrum and the *transmitter* is actually an infrared laser (see related article on page 7). A hole needs to be cut in a top panel for that purpose. Phase 3D's design permits the laser's addition with a simple interface. If you want to receive Phase 3D's highest frequency transmitter you'll need a telescope with an infrared detector - it ought to be an interesting challenge. This transmitter will transmit the telemetry beacon only.

Other avionics which need to be installed include the flight Monitor (MON) box and Integrated Housekeeping Unit (IHU-2) which have been undergoing final testing.

Next we'll start the power-up process using a ground power source. If everything's okay there shouldn't be any problems and Phase 3D will be ready for its final prelaunch

checkouts. We'll load the software in to the spacecraft's computers and check out the telemetry stream.

The main and auxiliary batteries were shipped installed in the spacecraft, but with their cables unattached and discharged. They'll be hooked up to a ground power charger and checked out one final time.

A leak check will be performed on the propulsion system to ensure that all of the connections are tight and nothing was damaged during shipment. It may be over a year before the main engine is fired so the system has to be leak-tight.

It may seem surprising, but until this point no RF testing has been performed on the spacecraft in French Guiana. We always need to remember that the key word in *Amateur Radio spacecraft* is *spacecraft* - without a working spacecraft the radios won't do anything!

We will have two Yaesu 736 transceivers and a variety of downverters to check out each of the spacecraft's different bands. Michael Fletcher, OH2AUE, and Peter Guelzow, DB2OS will be the key folks responsible for the RF testing.

Additional work needs to be done on the SBS ring including installing the pyro cables that send the commands to eject Phase 3D from the launch vehicle.

We also need to test the Check Out and Test Equipment (COTE). These are the cables that enable us to monitor Phase 3D's health while it's attached to the launch vehicle.

A final closeout inspection will then be conducted with as many eyes as there are available to look. The idea is that the more eyes the better chance of catching any problems. Extensive close out photos will also be taken to help us remember how everything was completed.

Then the solar panels will be installed. That is all except the one that covers the access to the fueling system, solar panel one.

At this point the final thermal coatings will be applied to the spacecraft to ensure proper temperature ranges through its lifetime. The bottom panels and top panels will be installed for flight.

We'll take Phase 3D off the rotisserie for the last time and put the spacecraft on a three-wheel roll-around cart. The cart gives us enough access beneath the spacecraft to



Phase 3D stored in shipping crate and ready for shipment to French Guiana.

install the bottom GPS antennas and on the side to install rail-like runners that will ensure that the deployment arms push Phase 3D out of the SBS smoothly. The bottom omni-directional sun sensors will also be installed and checked out.

There are about a dozen *red-tag* items that must be removed from Phase 3D before launch. These include dust-covers, shorting plugs, and other safety devices which are important while the spacecraft is being prepared but have to be removed before launch. The tags are bright red so they *stand-out* and as each one is removed it's noted in a checklist. Yes, the concern is very real that a red-tag item could be left in place and accidentally launched into space - it's happened with commercial spacecraft in the past.

Phase 3D is the first amateur satellite with major deployable mechanisms. From an engineering point-of-view a mechanical system is the most likely place for something to go wrong. So mechanical systems are designed to be as simple and reliable as possible with plenty of testing. On Phase 3D the solar arrays will be held in place with a strong cord. A pair of pyrotechnic cutters, originally intended for emergency parachute systems will be used. When the Phase 3D ground station sends an encrypted command the spacecraft computer will order both cutters to activate. As long as either cutter works the cord will be severed and springs will open up the arrays to their fully open position.

An even more critical system is the mechanism that holds Phase 3D to the launch vehicle. Phase 3D is held to the SBS by a set of matched compressed springs and three nuts. When the nuts are released the springs will push Phase 3D out of the SBS and away from the launch vehicle. The nuts are somewhat unusual for the aerospace industry. Instead of using explosive bolts the team chose to use pressurized nuts. Just apply pressurized gas to the nuts and they open up. A pyrotechnic chemical gas generator (think of the time as a kid when you mixed baking soda and vinegar together - only more so) will generate the pressurized gas which will activate the nuts. The integration team is responsible for checking out the nuts and other mechanisms in the SBS.

The team will check out each of Phase 3D's six equipment bays and inspect and close out each bay, except side 1. The solar arrays with



Various items to be used during the Phase 3D launch campaign were shipped with the SBS.

their hinges and wiring harnesses will be installed on sides 2 through 6. Panel 1 is left open because it includes the fueling panel.

By this point Arianespace has attached the SBS to its 2624 mating ring and will take that assembly back in to the spacecraft testing area. The flight umbilical sends our telemetry to the launch vehicle and permits the launch vehicle to send the command for us to separate from the vehicle. It will be installed on the SBS. Phase 3D will be raised on a crane and after alignment tests will be bolted to the SBS for launch. We will also install the pyrotechnic systems in to the SBS with shorting plugs in place to ensure safety.

The combined SBS and Phase 3D will then be moved to the fueling building. Fueling a spacecraft is considered an extremely hazardous task and Phase 3D will be more challenging than normal communications satellites. Most communications satellites use either a monopropellant or bipropellant system. Phase 3D has three separate propellants - monomethyl hydrazine fuel, nitrogen tetroxide oxidizer, and ammonia for the arcjet system. All are highly poisonous and require careful handling. It is most important to avoid any potential accidental mixing of the hydrazine and tetroxide which would cause a fire and possibly an explosion. The propellant loading is carried out in a secure building with reinforced walls by trained personnel from ASTRIUM (Lampoldshausen, Germany) wearing sealed suits with self-contained breathing systems. They'll do *dry runs* to ensure everything's in place before loading the actual propellants on the spacecraft. First 51 kg (112 lbs.) of

ammonia will be loaded, followed by 69 kg (152 lbs.) of monomethyl hydrazine, and finally 127 kg (280 lbs.) of nitrogen tetroxide. After leak checks to ensure that everything's okay the Phase 3D assembly will be moved back to the work area where:

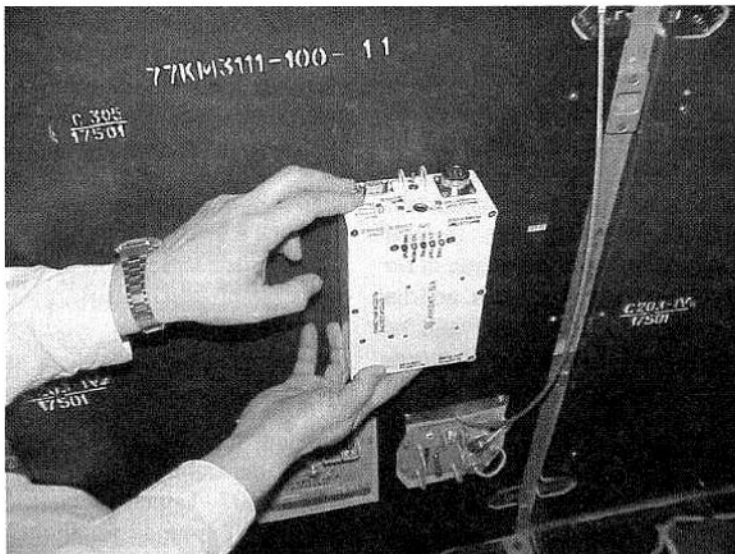
- A final inspection will be performed of equipment bay 1 and it will be closed out and its solar array will be mounted.
- A final test will be made of the solar panels using explosion-proof lamps.
- The entire fueled spacecraft and SBS will be weighed for launch.

At this point we can wait indefinitely or continue to prepare the spacecraft for launch, depending on whether or not the Ariane 507 launch vehicle and other passengers are ready for flight. From this point on all of the activities will be performed by joint Arianespace and AMSAT teams since they involve the rocket's components. Phase 3D and its test equipment will be moved over to the Batiment d'Assemblage Final Assembly Building (BAF) where Ariane 5s are assembled. Phase 3D will be mounted to the ASAP-5 which carries the other secondary payloads - STRV 1C and 1D. ASAP-5 is a version of the Ariane Structure for Auxiliary Payloads (ASAP) which flew the various microsats on Ariane 4 launch vehicles. Each time major components are mated there's a thorough check of all of the electrical and mechanical connections.

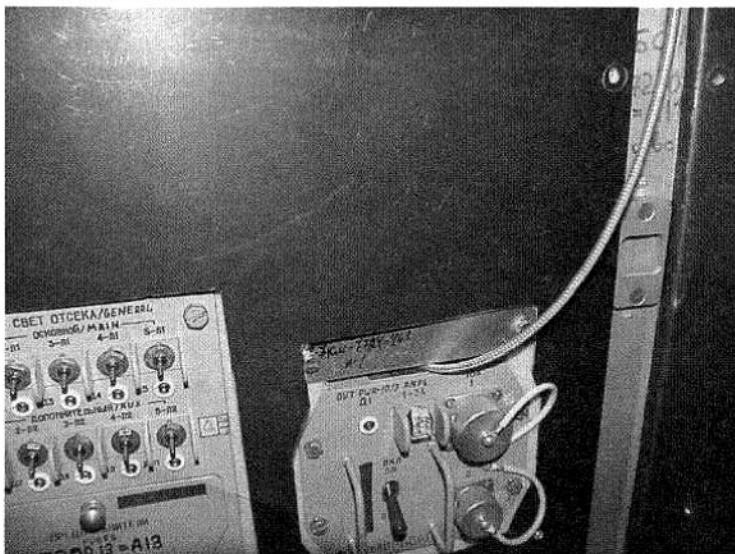
The combined Phase 3D and ASAP will be mounted on to the Etage a Propergol Stockable - Storable Propellant Stage (EPS), the Ariane 5's upper stage. The top adapter cone will be attached to the SBS and that's the last most of us will see of our satellite.



Participants of the ARISS review team meeting at the Khrunichev Space Center.



An ARISS team member holds the packet module near the location that it will be installed in the FGB. The actual flight unit walls are covered with Velcro. (photo by Lou McFadin, W5DID)



A closeup view of how the RF cable will be threaded through a panel within the FGB for temporary use of the ARISS antenna. (photo by Lou McFadin, W5DID)

The primary commercial satellite is mounted on top of the adapter cone. As things currently stand the primary customer for the Ariane 507 mission is Panamsat's PAS-1R satellite. By coincidence PAS-1 was Phase 3-C (AO-13)'s co-passenger in 1988. So it's good to be flying with an old friend.

There is one unusual final task about two weeks before launch. One of the AMSAT team members will lie down on a 'diving-board' like platform which extends through a hatch in to the adapter cone. On top of Phase 3D is a shorting plug which prevents the engine from firing by accident. This *safe plug* has to be removed and replaced with an *arm plug* before launch. Replacing the plug also connects an indicator line which verifies that the correct plug is installed for flight.

A dress rehearsal of the countdown and mission will be performed by the launch team with the participation of all of the satellites. This will occur about a week before the planned launch date.

About two or three days before launch Arianespace will publish the satellite coordinates for the launch broadcast. Arianespace purchases spot-time on commercial communications satellites and the exact transponder which will be available isn't known until the launch date is firm. Expect a special AMSAT News Service bulletin with this information. In the United States all Arianespace launches are broadcast on commercial C-Band unscrambled transponders.

When Phase 3D reaches orbit its solar arrays will be in their undeployed position wrapped around the spacecraft. They'll only be able to generate a limited amount of power. The spacecraft's runs on its own batteries from launch through separation from the launch vehicle. So the ground umbilical will provide a trickle charge until just before launch.

The launch day activities are extremely rapid with the Ariane 5 launch vehicle rolling out to its launch pad just a few hours before launch.

About 10 to 15 minutes after launch Phase 3D will be released and after three hours of outgassing, the spacecraft's beacon will be turned on by the computer. Finally Phase 3D will be where it belongs - in space. Then the real fun begins! ■

Infrared Laser on Phase 3D

Karl Meinzer, DJ4ZC; Dante Bauer, DH2FHB;

Dick Jansson, WD4FAB; and Hermann Günther

Translation by John J. Bubbers, W1GYD

In the summer of 1999, DJ4ZC came upon an idea to enhance the Phase 3D satellite with another experiment; a downlink on 360,000 GHz. Whether such an exotic experiment could be realized was not entirely clear.

Nevertheless, as a precautionary measure the space for it on the satellite was identified and a suitable cable was installed. On first glance, such an experiment was unacceptable, because Phase 3D was already faced with a weight problem. During the balancing of the satellite in the autumn of 1999 it appeared that such a laser module could be located, where weights were needed for balancing. This, then, was the actual starting point for the work on the laser project.

There were two Siemens infrared Lasers SFH482403 available from an earlier physics experiment, which produced an output power of 0.5 W at a wavelength of 835 nm. These components look like TO-3

transistors, but have a window in the cover for the light to exit; this exits at an angle of $10^\circ \times 20^\circ$. Additionally, the devices have a Peltier cooler to maintain the Laser temperature of 25°C , a temperature sensor, and a photo diode to monitor the light output.

Path Design

The basis for the successful completion of this experiment is the power budget of the path. It must be reliably determined that, in general, enough infrared light will arrive at the earth, allowing the laser to be received using amateur-available means. The path computation is analogous to that of the HF-paths; the transmitter illuminates a specific area on the earth from the satellite's assumed distance. The receiving antenna will pick up a small fraction of the power in the area. This power must be strong enough to be above the background noise. The calculation for this follows in two parts:

- Determination of the minimum power required by the receiver to be able to demodulate the signal
- Calculation of *antenna gain* to actually receive the minimum power from the given transmitted power.

For this experiment it was assumed that only a maximum of 400 bit/s could be transmitted (for example, the Phase 3D telemetry) and that further, reception is possible only on nights with clear skies, that is, when no interfering light deteriorates the communications. Under these conditions about 30 percent of the light will be absorbed by the atmosphere, that is, 70 percent will reach the ground. Further it was stipulated, that a *receiving antenna* with a diameter of 10 cm should be adequate

The attainable sensitivity of the receiver is heavily dependent on the technology used. At this point we made an exotic assumption, namely, that a detector of the *photon counter* type with a high quantum efficiency level would be used. These detectors are in the

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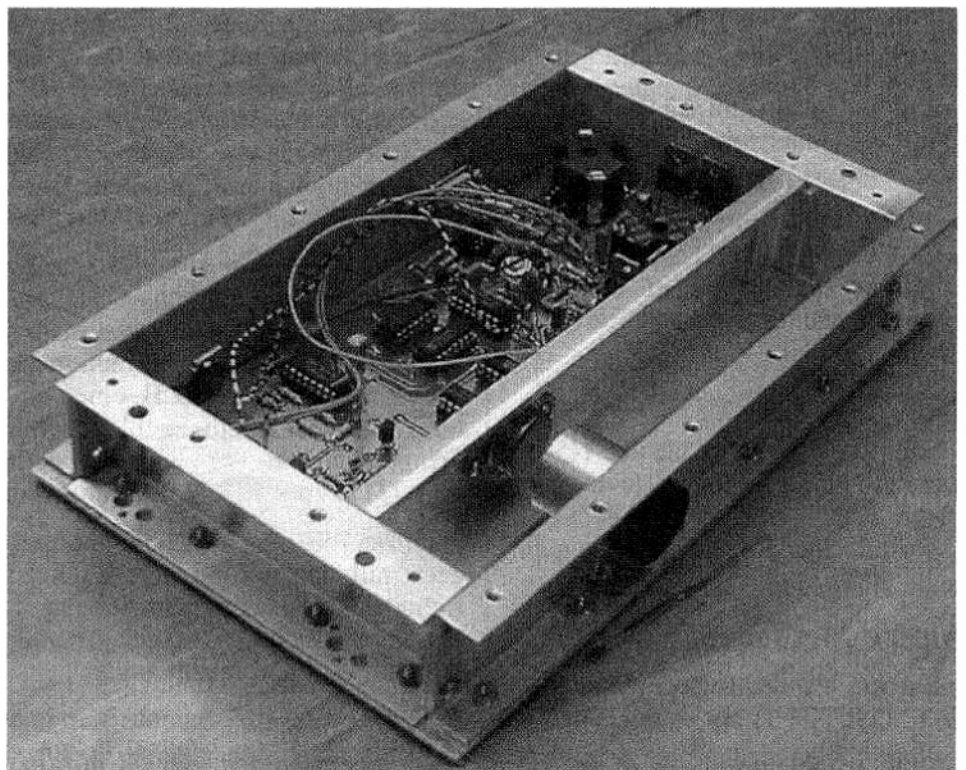


Figure 1. Phase 3D's Infrared Module.

The module is ready to fly and at the start of the launch campaign will be mounted in Phase 3D's Bay 5 on top of the Monitor Experiment (Figure 1). A method for cutting a hole for the lens aperture through the top of the spacecraft has been tested and approved.

In the block diagram provided as Figure 2 one sees four function groups:

- **Power Supply:** The module uses 10 V internally, and is turned on by the on-board computer. In the IR module there is a five second delay in the power turn-off; by this means the laser can be keyed with the turn-on control without having to re-stabilize (PLL capture etc.) the internal switching after each keying event
- **Modulation:** The satellite's EB signal (400 bit/s Exclusive-Or with the clock) feeds a PLL as the main clock source to synchronize all switching events. The EB signal is locked with a 1600 Hz Exclusive-Or gate; this modulation along with an auxiliary carrier makes possible improved receiver performance capability.
- **Laser Keying:** The laser is fed with a constant current in the on-state, which serves as the keying controller, operating at 50 kHz. In the off-state the transducer is blocked off. The transducer is fast enough to follow the keying without any noticeable leading edge waveform loss.
- **Peltier Cooling:** There is also a transducer to feed a current to the cooler. This current is controlled in accordance with the temperature of the laser. The temperature measurement is from an NTC, which is a part of the laser component.

- **Frequency:** 360,000 GHz (approx. 835 nm)*
- **Output Power:** 250 mW average, 500 mW peak @ 50 percent duty cycle
- **Modulation:** 1600 Hz square wave auxiliary carrier, BPSK modulation at 400 bit/s, same as the Phase 3D telemetry
- **Radiation Characteristics:** Radiation direction: in the Z-axis of the satellite
- **Radiation Format:** approximately elliptical with a width of 1/30 rad (3 dB) in the plane of the satellite's X-axis *; 1/50 rad width (3 dB) in the plane of the satellite's Y-axis. *
- **Effective Radiation Area:** 1/2000 steradian (approximately 41 dBi "antenna gain")
- **Polarization:** linear, E-direction parallel to the X-axis. *
- **Spectrum Characteristics:** Multi-mode, approximately 2 nm bandwidth

* These specifications are not yet firmly established; there could still be changes, which will be disclosed at a later time.

Outlook

Naturally the laser experiment will appeal mainly to the experimenters of the amateur community. Because of the small footprint of the illuminated ground zone the operating times and zones must be planned and disclosed in advance.

The on-board computer will accordingly control these plans for the location of the satellite

The on-board computer will then control the location of the area in accordance with the satellite location plans.

After some operating experience it will be determined whether the apogee range delivers sufficiently strong signals; if not, the laser operating time in the orbit-schedule can be shifted, to one in which the satellite is closer to the earth. The illuminated ground area will then, naturally, be smaller.

In total, we hope that the infrared laser on Phase 3D will offer additional, interesting experimental possibilities, and further, this is the first entry of a *laser downlink* from satellites. ■

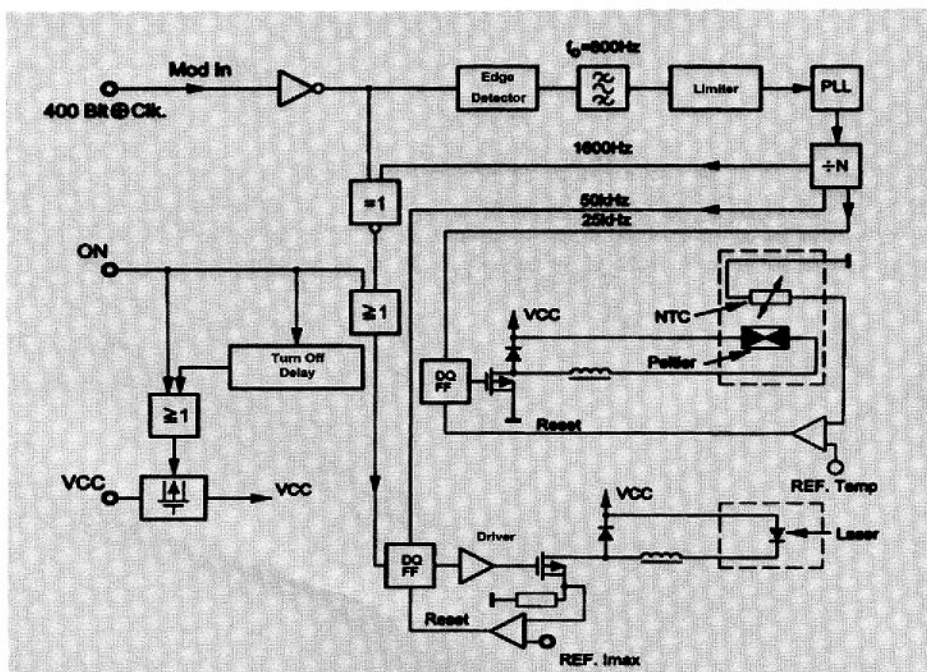


Figure 2. Block Diagram for the Phase 3D Infrared Laser.

Phase 3D New Bands, Part 2: Antennas and Transmitting

Ed Krome K9EK, k9ek@amsat.org

Phase 3D New Bands, Part 1 (*The AMSAT Journal*, July/August 2000) discussed the basics of satellite operation on the higher frequencies, concentrating on reception. Part 2 will address antennas, transmitting requirements and equipment

Uplinks

Uplinks on the higher bands get a little more complicated than downlinks. For transmitting, there seems to be an exponential relationship of cost versus frequency. While everything that was said for downlinks applies for uplinks, feed line loss assumes even great significance. It's one thing to know that you are losing some noise figure in an overly long feedline, but think about it from a transmitting cost point of view. A 3-dB line loss between the transmitter and the antenna absorbs fully 1/2 of your transmitter output power! The two standard ways of dealing with this problem are 1) lower loss feedlines and 2) mount the amplifier closer to the antenna. Lots of opportunities for clever approaches here.

EIRP

Analyses of the power required to reliably link to the satellite are based on signal to noise ratio requirements and path loss calculations. Here we become acquainted with a new designation, EIRP. When doing link margin analysis, we really don't care what the individual values of transmitter power or antenna gain are; what is important is the total signal strength being transmitted. This quantity is referred to as EIRP, or Effective Isotropic Radiated Power. EIRP is derived from the sum of transmitter power (at the antenna) and antenna gain. This EIRP number is referenced to a hypothetical free-space single point source antenna called an isotropic radiator. An isotropic radiator radiates power equally in all directions from a single point. The measured field strength is the same at every point a given radius (a sphere) from the center. It is therefore said to have 0 (zero) dB gain. We get antenna gain by concentrating our total energy into a smaller portion of the sphere. We use a logarithmic relationship (decibels) to relate the amount of energy concentrated in the smaller portion to energy in a similar area in the original sphere. That's what an antenna does; it concentrates energy into a smaller area. The field strength is, of course, highest in the center of that portion of the sphere and

falls off away from the center. Antenna beamwidth is usually defined as the included angle between the points where the power level falls off 3 dB from the highest value. Values are typically given for two planes (E & H) at right angles to each other. Note that some antenna gains are referred to as dBi, which is decibels relative to an isotropic radiator and some are termed dBd, which is relative to a dipole. A dipole theoretically has 2.15 dB more gain than the isotropic radiator, so dBd numbers will appear lower than dBi numbers. To relate one to the other, simply add or subtract this difference.

As a general rule, don't get too taken up by small differences in published gain numbers. There are a lot of things that have been done to make numbers "look" better, and the antenna itself is not the whole system. In the words of Robert Heinlein, *TANSTAAFL*, or *There Ain't No Such Thing As A Free Lunch*. While some antennas are more efficient than others, larger/longer will always make more gain than smaller/shorter. So, is larger always better? Not necessarily. For our use, we have to keep our antennas pointed at a moving target in the sky that we can't see. The narrower the "beamwidth" (that reduced section of the sphere we talked about earlier), the more difficult it is to keep the antennas physically pointed at the satellite. Ideally, we want to use as low a gain antenna as will provide satisfactory communications. The tradeoff is that the lower the antenna gain, the higher the required transmitting power to maintain some required minimum EIRP.

So how much EIRP will we need for the higher bands? In 1995, Frank Sperber

DL6DBN published an analysis (Table 1) that gives EIRP but does not include much detail on the assumptions used to get there. Franklin Antonio N6NFK's analysis (dated 7/4/00; available at http://members.aol.com/n6nfk/P3D_uplink_budget_3.xls) is much more detailed. Mirek Kasal OK2AQK published a simplified analysis (taken from AMSAT e-mail reflector dated 7/14/00 and published on page 30 of this issue). For 1269 MHz (the band common to all three analyses), the following numbers come out: Sperber predicts 23 dBWic (10 watts to a 12-turn helix). Kasal predicts 24.4 dBWic (8.7 watts to a 15dBic short backfire antenna (like the antenna on the satellite itself) or 28 watts to a short 10 dBic helix). Antonio's numbers come out somewhat higher, but include a speech compression factor, line loss, polarization loss and pointing error: (at the risk of misinterpreting his work): 33 dBWic (20 watts to a 12 foot long Down East Microwave 45 element loop yagi (20 dBi) for a 15 dB S/N at the transponder). Note that dBWic means decibels relative to a 1-watt reference from an isotropic radiator, circularly polarized. Whatever the EIRP, we need some combination of antenna gain and transmitter output power to equal this EIRP.

EIRP assumes the same polarization (horizontal or vertical) at each end of the link. Of course, with satellite operation, such terms as horizontal and vertical are meaningless since space provides no frame of reference. Instead, most satellite signals are circularly polarized. All Phase 3D up and downlink signals will be right hand circularly polarized, as discussed in Part 1. Therefore, we use the term EIRPc to indicate that the polarization of both ends of the link



Figure 1. 13cm Transverter from SSB Electronic.

is circular. This assumes that both ends of the link are the same hand; perfect circularity with reversed hands of polarity will effect 30 dB loss. The penalty for linear polarization on one end and circular on the other is theoretically only 3 dB, though this may vary since no rotating wavefront is completely circular. As pointing angles increase, circularity becomes more elliptical, which, in effect, makes it function more like linear polarization. This can work either for you or against you. The best idea is to have enough link margin (read that as power) to compensate for changing conditions, but only use as much as required to attain the same downlink strength as the beacon.

Getting the Power to the Antennas

Now the practical trick is to get the transmitter power to the antenna. Large copper hardline is nice and low loss, but expensive and hard to handle. CATV hardline, the aluminum jacketed 75-ohm variety, is a useful and practical alternative. Ah, you ask, my radio is 50 ohms; what about impedance mismatch with 75 to 50 ohms? Yes, that is a problem, but that only results in a 1.5:1 SWR, which relates to some pretty insignificant power loss. A bigger problem is how to satisfactorily attach waterproof connectors to either end of the line and not introduce really bad mismatch. It is also possible to add in-line impedance converters, 61 ohm 1/4 wavelength line sections, that convert 50

ohms to 75 ohms. These are beyond the scope of this paper.

A reminder: generally, we see the satellite when it is above the horizon. This says that antenna height is not as critical as it is for terrestrial use, since antennas are usually pointing at some angle upward. One way to eliminate feedline loss is to reduce the length of the feedline by mounting the antennas close to the shack and to the ground. Having an antenna that is not useable in certain directions (houses, trees, etc.) may be a reasonable tradeoff to the problems imposed by long feedlines.

1269 MHz L-Band Uplink

L-band is the highest band for which commercial transmitting equipment is readily available.

Plug-in modules for the Yaesu FT-736R convert it to a 23cm transceiver with 10 watts output. ICOM has the IC-1271 and 1275, complete transceivers for 23 cm. Note that while both these radios are no longer manufactured, they are readily available used. Commercial offerings change frequently, so the best guides are magazines and web sites for the respective companies.

The previously mentioned link margin analyses show that, while 10 watts might provide acceptable SSB communications, there isn't much margin for feedline loss or other system problems.

Mounting an FT-736R at the top of your tower isn't something many operators would relish. A more practical alternative is detailed in the 1998 through 2000 ARRL Handbooks. The article, *An Integrated L-Band Satellite*

Uplink

Band	EIRPc	TX-power	Antenna
146 MHz	20 dBWi	10 W 50 W	7 Element X-Yagi Crossed Dipoles
435 MHz	21 dBWi	10 W 40 W	10 Element X-Yagi Crossed Dipoles over Reflector Plane
1270 MHz	23 dBWi	10 W	12 turn Helix
2400 MHz	27 dBWi	5 W	60 cm Parabolic Dish
5670 MHz	34 dBWi	10 W	60 cm Parabolic Dish

Downlink

Band	GND-PEP/QSO	Antenna	S/N
146 MHz	-155 dBWi	7 Element X-Yagi Crossed Dipoles over Reflector Plane	23 dB 16 dB
435 MHz	-157 dBWi	10 Element X-Yagi Crossed Dipoles over Reflector Plane	24 dB 13 dB
2400 MHz	-167 dBWi	60 cm Parabolic Dish 14 turn Helix	26 dB 18 dB
10450 MHz	-184 dBWi	60 cm Parabolic Dish	24 dB
24 GHz	-197 dBWi	60 cm Parabolic Dish	13 dB

Note: The above are the best estimations from the AMSAT-DL (AMSAT-Germany) web site. Following are notes on the various types of antennas indicated and terms.

"Crossed dipoles over a reflector plane" is a pair of center-fed dipoles, 90 degrees to each other, fed 90 degrees out of phase, to produce right hand circular polarization, suspended over a reflective sheet. A very simple circularly polarized antenna with a predominantly vertical radiation pattern. Tracking not required.

"X-Yagi" is a right-hand circularly polarized yagi antenna made with 2 sets of elements at right angles to each other. Also referred to as a "cross yagi". A "7-element X-yagi" has 2 sets of 7 elements in each set on a single boom. A relatively small, directional yagi. Must track the satellite.

"60 cm parabolic dish" is a 24-inch diameter parabolic dish antenna with the appropriate feed for the band in use. Must track the satellite.

"GND-PEP/QSO" is the signal strength of the satellite's signal on the ground.

"EIRPc" is Effective Isotropic Radiated Power, circularly polarized, in decibels (dB) relative to 1 watt. This is effective transmitted power from a combination of actual transmitter watts and antenna gain, referenced to an "isotropic" (fictitious point source) radiator.

Table 1. Equipment Requirements for the Groundstation. Downloaded from <http://www.amsat-dl.org/gndstn.html> by Frank Sperber, DL6DBN

Antenna and Amplifier by K9EKL suggests mounting a separate 10+ watt amplifier directly behind a 15 turn helical antenna, right up on the crossboom. A practical problem plaguing the use of helical antennas is the difficulty of physically supporting the antenna. The approach detailed in the article uses a small amplifier, mounted on the boom of the helix antenna itself but behind the cross boom, as a counterweight for the helix. The proximity of the final amplifier to the antenna virtually eliminates feedline loss. But the design takes advantage of feedline loss (yes!) by using the attenuation of the feedline from the transmitter in the shack up to the antenna-mounted amplifier to reduce the level of the signal from the shack transmitter down to the input level required by the amplifier. So, 10 watts in the shack though a 10 dB loss feedline gives 1 watt at the input to the tower mounted amp; exactly what the amplifier needs to give 10-15 watts out. See the ARRL Handbook for more details.

And Higher Still: S and C Bands

Here we enter the depths uncharted by Kenwood, ICOM or Yaesu. Gear for this band will make you intimately familiar with names like Down East Microwave and SSB Electronic (Figure 1). Because at this frequency and higher, they are presently the only games in town. Both carry transverters, amplifiers and antennas for higher frequencies.

Generally, transmitting on all higher bands is handled in a similar fashion. You couple a VHF transceiver to a transverter in the shack or up on the pole, then find some way to get the power to the antenna with minimum loss. UHF transverters are available with milliwatt level power outputs, where it is assumed that you will use external amplifiers, or higher levels. Each user has to evaluate his own requirements and situation and figure out what works best for him.

S-Band Transmitting

The basic requirement is an S-band transverter set up for the proper frequency range. Remember that satellite operation is on 2401 (primary) and 2446 MHz, whereas terrestrial operation is on 2304 (the Americas), 2320 (UK, Europe, former Soviet Union) and 2424 (Japan, Australia). A typical transverter is shown in Figure 1. The real trick is to get the power to the antenna. I have explored several approaches to transmitting on this band. For the

brute-force approach, I build tube-type amplifiers for 13cm, using both the 7289 planar triode (see Figure 2) and a large Russian triode. Unfortunately, the finicky nature and high voltage requirements of vacuum tube amplifiers make them rather complicated to use. But if you want real power on this band, tubes are the only way to go. Since the projected link margins indicate that 5-10 watts to a small dish will be adequate, a better approach for our use is probably a 10 watt solid state amplifier, remote-mounted at the antenna in similar fashion to that described for L-band. Down East Microwave has recently introduced a 1-watt in, 15 watt out amp that appears well suited to this application (Figure 3). As with L-band, you will have to pay attention to matching the output power of your in-shack transverter less feedline loss to the input requirement of the amplifier.

C-Band Transmitting

Feedline losses on 5668 MHz are so high that I don't think that there is any alternative to mounting the entire transverter and final amplifier right out at the antenna. Or mounting the antenna right at the shack. Both Down East and SSB Electronic will offer amplifiers for this band. Occasionally, some really useful amps appear on the surplus market. These were used by the telephone companies for point-to-point links on C-band. I was fortunate enough to find one a few years back (it took me a year of active searching) that has over 40dB gain and puts out 10 watts. It is as large as a shoebox and quite heavy. This amp requires

-48 VDC at 3 amps, hardly something you can pick up at your local Radio Shack. This amplifier has so much gain, that I can work around some feedline loss.

As a personal solution, I designed and built a transmit mixer, similar to the previously discussed

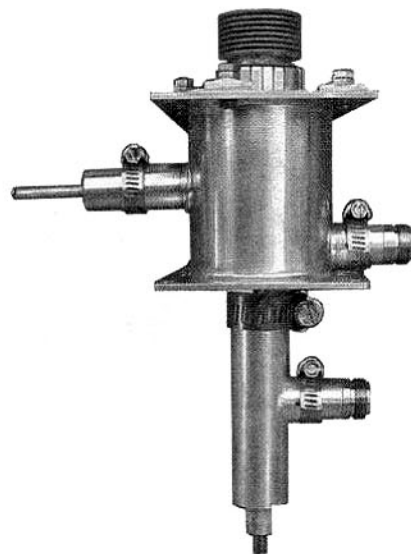


Figure 2. 13cm Amplifier using 7289 Planar Triode Tube.

device that I built for 10450 MHz reception. It uses the same arrangement of a 6/4 wavelength ring mixer to combine a 146 MHz IF signal with the output of a Frequency West brick phase-locked oscillator. C-band bricks are much more common at hamfests than are the X-band versions. All the same problems of the need to be re-crystaled and tuned apply, as does the -19 VDC requirement. The remainder of the transmit converter consists of a pair of 3/4" pipe cap filters that select the desired mixing product and route it through a pair of Mini-Circuits ERA series MMIC's. The entire package puts out -2 dBm on 5668 MHz and provides a satisfactory driver for the shoebox amplifier, but without much

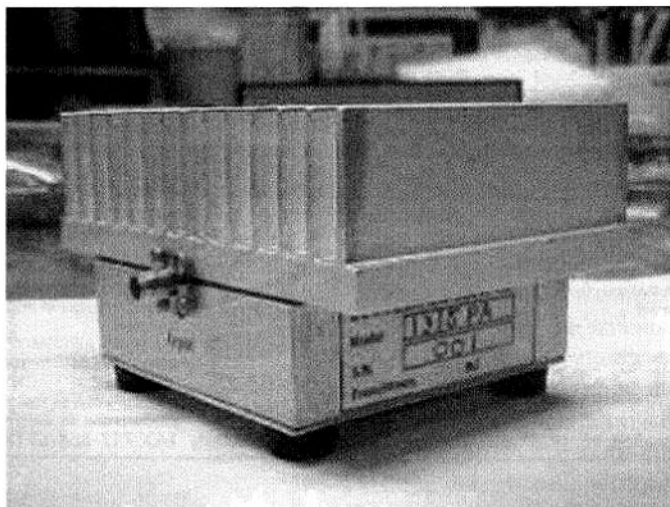


Figure 3. 13cm 15 watt Amplifier from Down East Microwave.

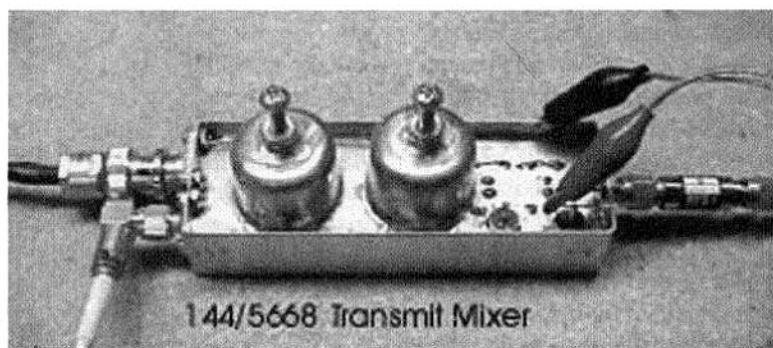


Figure 4. 144 to 5668 MHz Transmit Mixer by K9EK..

headroom for line loss (Figure 4). It really needs another stage of amplification. My intent is to *package* the amplifier, mixer and brick LO in a box that I can haul up my tower and hang in place when I want to experiment on C-band.

Multi-band Antennas

Sperber has conveniently related most of his high frequency transmission and reception to a 60cm parabolic dish antenna. Which of course begs the question: can I use the same 60cm dish for more than one band? I think that the answer is both yes and no. For

reception, we have already said that mounting more than one dish feed in one dish is satisfactory. But transmitting is different. The power transmitted from one feed will be picked up by the second feed, even if the frequencies are widely different. Solid state devices do not like large amounts of thermal energy applied to their junctions. You can burn out a junction from the back door also.

The commercial method of getting around this problem is through the use of ferrite isolators and filters between the output devices and the antenna feeds. Isolators are

3-port non-reciprocal devices that allow transmit energy to pass from an input port to an output port with little loss. But energy incident on the output port is routed to a terminating resistor and isolated from the input port. Clever devices, but not common in *normal* channels. Also, they don't have extremely wide bandwidths, so a 10 GHz isolator might not protect a 10 GHz preamp from a strong 2400 MHz transmitter signal. This is where bandpass filters are required. A more practical method is to use relays that disconnect the unused transmitter output or receiver input. These should generally be wired so that the transmitter output or receiver input is terminated in a 50-ohm load to ground. There just isn't any really good way to operate full duplex where both bands use a single dish.

The only alternative to isolators or multiple high-priced relays is not to use the same dish for transmitting on more than one band or for both transmitting and receiving. Multiple dishes get physically cumbersome, but are a practical method to allow full duplex operation, as well as keeping one transmitter from killing another.

Summary

The higher bands on Phase 3D offer some great opportunities and challenges. Table 1 provides DL6DBN's complete predictions of up and downlink station requirements. See you on Phase 3D! ■

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- Down East Microwave, 954 Rt. 519, Frenchtown, NJ 08825, 908- 996-3584
www.downeastmicrowave.com
- SSB Electronic USA, 124 Cherrywood Dr., Mountaintop, PA 18707, 570-868-5643 www.ssbusa.com

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Putting Together a L/S Band Antenna System for the Phase 3D Satellite

Jim Koehler, VE5FP and Eric Rawson, KN6KC

One of the first decisions required of someone new to ham satellites is the choice of bands and modes. The most popular choices in the past have been 144 and 430 MHz. But deep space satellite communications require high gain antennas and high gain antennas for these bands are large and cumbersome. With the arrival of the Phase 3D satellite, it seems certain that activity on the higher bands will grow substantially over the next few years. One of the most attractive band pairs is likely to be the L/S mode, which uses 1.2 GHz for the uplink and 2.4 GHz for the downlink. High-gain antennas for these two bands can be quite compact and exhibit low wind resistance. This article describes our approach to a L/S band antenna system for Phase 3D.

Helical antennas are very convenient for microwave satellite work. They are circularly polarized and, for these frequencies, small, mechanically simple and robust. The circular polarization means that fading caused by Faraday rotation of the uplinks and downlinks through the ionosphere is eliminated. Because helices are small and light (for 1.2 and 2.4 GHz, at least), antenna rotator systems can be constructed from TV rotators (1). Finally, because they are broadband, they don't have to be built to really close tolerances and this makes them very reproducible. Ed Krome has described the requirements for a helical antenna system for the Phase 3D satellite's 1.2 and 2.4 GHz transponders (2).

Although helical antennas are simple to build and simple to match, there is a catch – it requires some microwave test equipment to do the matching! Not many of us happen to have a 1.2 or 2.4 GHz return-loss bridge (in fact, very few of us do!). Fear not, in this article, we'll describe how to build a very simple antenna bridge that'll make matching these antennas (or any other antennas at these frequencies) a snap.

The characteristic impedance of a helical antenna is somewhere near 140 Ohms. We usually want to match this to 50 Ohms. The standard matching technique is to make the first quarter turn (which is one quarter of a wavelength long) into a quarter-wave matching section; the characteristic impedance needed is about 84 Ohms, the geometric mean of 50 and 140 Ohms. This quarter turn is either flattened or has a piece of sheet copper soldered to it in order to reduce its impedance and is bent to be parallel to the reflector at the back of the helix forming a quarter-wave transmission line. The impedance of this line is then adjusted to 84 Ohms by changing the spacing between it and the reflector.

This last step is usually dismissed in a single sentence, however, it is the crux of the process! How do you know when you've gotten it to be 84 Ohms (i.e., when you've gotten a proper match)? The answer is that you have to have some test equipment to do so. If you have a transmitter with an SWR meter for the frequency, you just adjust the spacing until you get the lowest SWR.

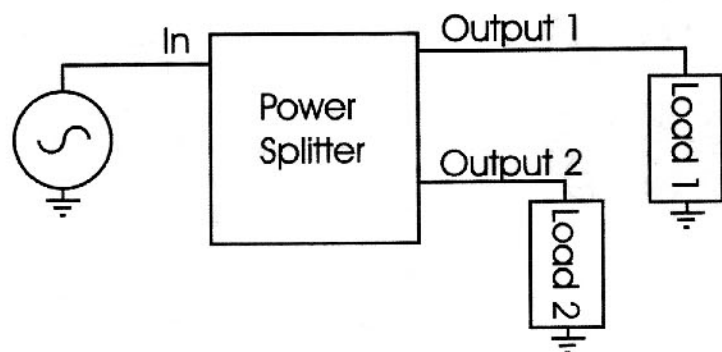
Another method is to use a signal generator and a return loss bridge and match the antenna by adjusting the spacing until you get minimum reflection. Return loss bridges are commercially available and widely used for matching things like amplifiers to coaxial line.

A third method is to use a signal generator and a simpler, more primitive bridge. One side of the bridge is connected to a standard 50-Ohm termination and the other side is connected to the antenna. The antenna is then adjusted until the bridge is balanced. The bridge is balanced, of course, when the impedance of the antenna and the standard termination are the same. That is the method we used and this article describes how you can build a simple antenna bridge with its own microwave signal generator built in. You will need two of these, one for 1.2 GHz and one for 2.4 GHz, but they are very simple to make and very reproducible. Having these bridges, it is then easy to build the antennas that are described later.

Circuit

The heart of the bridge is a RF transformer called an in-phase power splitter. A signal fed into the power splitter produces two signals, one at each output port of the power splitter, which are equal in amplitude and in phase with one another. These two output ports are connected to two loads as shown in Figure 1. If the two loads are identical, then the voltages appearing at each of the two loads will have the same amplitude and phase. If the loads differ in impedance, then the two voltages will differ in amplitude or phase or both. A simple diode detector is connected between the two loads to give a DC output that is proportional to the difference in RF voltage at the two loads. If the voltages at the two loads are identical in amplitude and have the same phase, the detector will give a DC output of zero. If there is a phase or amplitude imbalance, then the DC detector will give some output.

We use this circuit by connecting a standard 50-Ohm termination to one output port of the power splitter and the antenna to the other. The circuit will only produce zero DC output when the antenna has the same impedance as the standard termination: 50 Ohms resistive. So, to match the antenna to 50 Ohms, we change the spacing between the $\lambda/4$ matching section of the antenna and



but the losses are not important for this circuit. The prototype boards were made by using a Dremel® tool to grind away the copper from parts of one side of a plain double-sided board but a printed circuit board is available (4). If you choose to use the Dremel® tool 'technique', the only really critical dimensions are those of the leads between the power splitter outputs and the connectors. It is important that the two lead lengths from the power splitter to the connectors are equal and that the line width is close to that shown in the drawing. We have made several prototypes this way (i.e., by grinding the pattern onto a piece of PC-board with a Dremel® tool) with widely differing layouts of the rest of the components but keeping these lines the same width and of equal length; they all worked well.

There are holes drilled through the board for the leads of the regulator, for a test point at the wiper of the potentiometer and at the pad for the DC output to the meter. On the bottom surface of the board, you will need to 'mill' the copper from around these holes (all except the center lead of the voltage regulator) so that the leads will not short to the ground surface. This can be done by taking a small, say 1/8", drill bit in your fingers and giving it a few twists with the point of the drill in the hole at the bottom surface.

Most of the components, including the VCO and the power splitter, are surface mounted. The template is laid out for Type 0805 sized chip capacitors and resistors; these are 2 mm long by 1.25 mm wide. Sam Ulbing has given a good introduction to surface-mounted assembly and, if you haven't done any before, we urge you to read his four articles before beginning construction (5). A test point is put at the potentiometer wiper by bending a hairpin out of busbar wire, putting it through the two holes from the top so that the top of the loop is just about 1/4" above the top surface of the board. It is then soldered on the top surface of the pad and the excess wire cut off on the bottom of the board. The loop thus formed, sticking up above the circuit board, is a convenient place to clip a test lead from your voltmeter when you are ready to set the VCO to the proper frequency.

The regulator and its by-pass capacitors are mounted on the underside of the board and should be put on last. Holding the voltage regulator so that you can read the writing on it, bend the leads away from you by 90

degrees. The regulator can then be mounted from the back of the board with the leads sticking through to the top. The center lead should be soldered to both sides of the board but the outer two leads only to the top. The positive leads of the small electrolytic capacitors are connected to the input and output of the three-terminal regulator. The negative leads of these capacitors are soldered to the bottom surface of the pc-board.

The first prototypes of this circuit were assembled and enclosed in a 'box' made from scraps of PC-board material. A photograph of two of these prototypes is shown in Figure 5. Lids are not really necessary. If you do choose to assemble it this way, make sure you solder both the top *and* bottom surface of the circuit board to the sides of the box. This provides a good low impedance connection between the bottom circuit board ground plane and the top ground plane.

Although this technique is electrically excellent, the appearance leaves something to be desired. A more attractive instrument can be made by putting the assembled board inside a Pomona box (6). If you choose to go this route, you will need to solder multiple feed-thru wires between the top surface and the bottom surface of the PC-board to provide the low-impedance connection between the top and bottom ground planes. The holes for these wires are shown as the rows of dots on 0.1" centers along the sides and elsewhere on the template, Figure 3. These wires are the first things that should be soldered to the board, leaving the rest of the components until later. Start by cutting some approximately 1/2" (1 cm) lengths of old resistor leads or bus bar wire. Put the board on a flat surface and lay a few of these

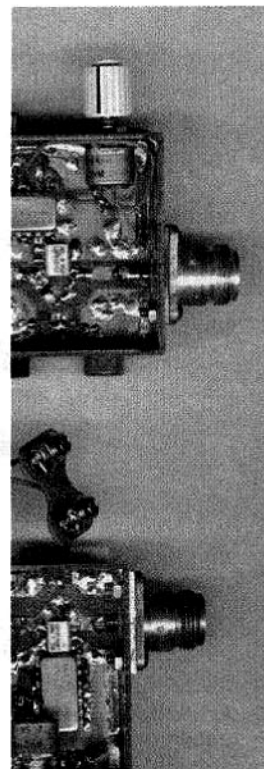


Figure 5. Bridge Circuit Prototype.

leads under it to lift it above the surface by the thickness of the leads. Then, stick other leads into the drilled holes and solder them to the top surface. You will find it easiest to solder the four leads closest to the corners first because these leads will then support the board above the surface. Solder in the rest of the wires on the top surface and clip them off. Then, turn the board over and solder all the wires sticking out of the bottom copper surface. Finally, take a fine file and smooth off the clipped wire ends on both the top and bottom surfaces of the pc-board.

Having done this, you can then mount the rest of the components as described before. For the Pomona box versions of this circuit,

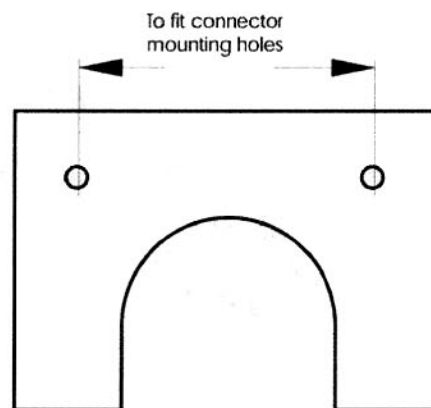


Figure 6. Ground of PC-board to case.

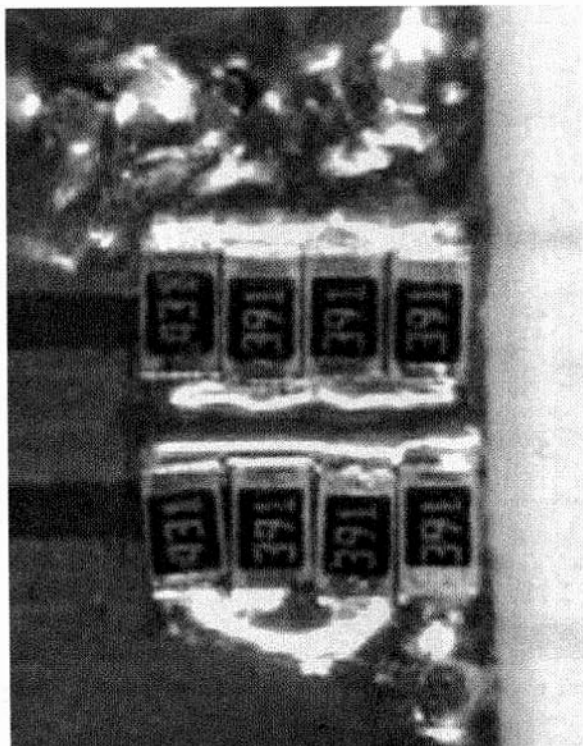


Figure 7. Eight chip resistors in parallel along the reference transmission line.

we also need to have some way of providing a good low impedance connection between the ground of the PC-board and the ground of the case. This is done by cutting pieces of shim brass to the pattern as shown in Figure 6. These pieces are then later mounted on the inside of the Pomona box by the two top screws of the connectors and the tabs soldered to the top surface of the pc-board in the vicinity of the connectors.

The assembly of the Pomona box version is not complicated but the pieces are fairly small and it is important to do them in the right order. First, solder a piece of insulated

hookup wire to the pad for the positive output meter connection. There is a hole drilled on the pad. The corresponding negative lead is just soldered to the adjacent ground-plane surface of the PC-board. The cathode lead of diode, D1, should be cut off to about 1/2" in length and the last 1/16" bent over. This can then be soldered to the pad at the input side of the voltage regulator, leaving the anode lead of the diode sticking up from the top surface of the board. This lead will later be soldered to the center terminal of the input power connector after the board has been installed in the box.

You have to drill all the holes you need in sides of the Pomona box next. The

input supply voltage enters the box through a coaxial power jack. The current required for the VCO is only a few tens of mA so the smallest size is big enough. The output to the meter can be a similar jack or just via the insulated hookup leads routed through two holes drilled in the box. In either case, the holes in the box should be drilled so that they are *above* the board when it is assembled in the case so that there is enough clearance for the jacks and the components on the assembled board. The five holes for the Type-N connectors should be drilled next – four for mounting screws plus a central hole for the center pin.

The PC-board is held in place by being soldered to the center pins of the two Type-N connectors. These connectors should be mounted in place first but only by the bottom two screws of each connector. The pc-board is then maneuvered into place and soldered to the two center pins. The pieces of shim brass are then bolted into place, bending the tabs so that they just touch the surface of the PC-board. These are then soldered to the PC-board ground surface. You can then mount the input power and output meter jacks and connect them to the lengths of hookup wire attached to the PC-board.

As originally designed, we assumed that the reference load for the bridge would be a 50-Ohm coaxial termination. Therefore, the reference port would be a Type-N connector just like the antenna port. These connectors are mounted symmetrically on either side of the box, whether pc-board or the Pomona box; as shown in Figure 5. It later occurred to us that there might be many would-be constructors of this instrument who did not have a good 50-Ohm termination at hand. What is the alternative?

What you want at the reference port is a load which is 50 Ohms and which is purely resistive at the 1.2 and/or 2.4 GHz. To reduce the inductance of resistive loads, one normally uses several resistors in parallel. Surface-mount chip resistors have a pretty low inductance to start with and we thought that putting a number of them in parallel would be even better. Accordingly, we assembled several of the prototypes where we put eight chip resistors in parallel along the reference transmission line. This is shown in the photograph in Figure 7. The resistors are six each of 390 Ohms plus two each of 430 Ohms. The calculated total resistance of this combination turns out to be 49.9 Ohms – close enough considering the tolerances. This distributed resistor acts as a reasonably good load at 1.2 GHz but is nowhere near as good at 2.4 GHz. We recommend, therefore, that you use an external termination for the 2.4 GHz version of this unit.

Using these resistors instead of a reference termination means that the assembled instrument just needs one Type-N connector – that for the antenna port – and no 50-Ohm coaxial termination. One minor complication resulting from making your own internal 50-Ohm reference is that there is only one Type-N connector on the box instead of two. The PC-board is therefore supported only by the solder connection to

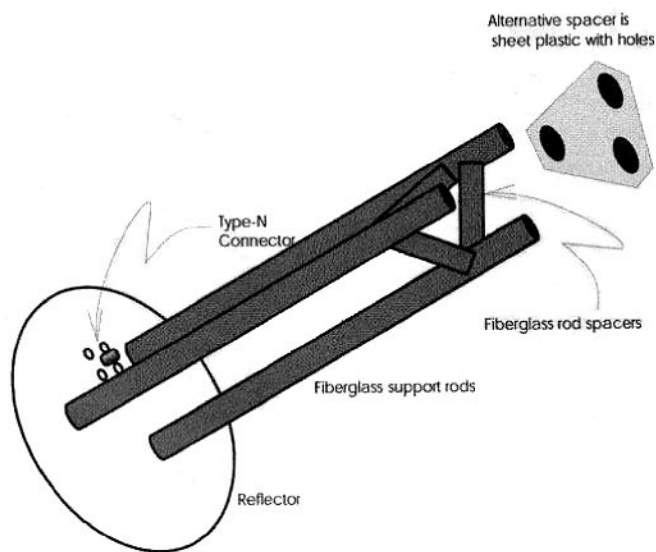


Figure 8. Helical antenna diagram.

the center of the connector on one side and the grounding tab on the same side. However, the PC-board is small and light and this single-sided support is good enough for all but the roughest handling.

Antennas

AMSAT-DL has specified the uplink radiated power needed to contact Phase 3D on 1.2 GHz and calculated the expected total path loss on the 2.4 GHz downlink (7). These numbers allow us to calculate the antenna gain required. Assuming a 10 W transmitter on 1.27 GHz, you will need an uplink antenna gain of about 13 dBi. This can be provided by a 16 turn helical antenna. From downlink noise considerations at 2.4 GHz, for a received S/N of ~20 dB, and using a reasonably good low-noise preamplifier mounted at the antenna, you will need a 28 turn helical antenna. Note that these sizes are somewhat larger (i.e., they have more turns and, hence, more gain) than Ed Krome specified in his article. However, they are still physically small and light and the extra gain will give a little extra margin for communicating with the satellite.

The design center frequencies for the antennas are 1.27 GHz for the L-band uplink antenna and 2.42 GHz for the S-band downlink antenna. Helical antennas are very broadband and this is an asset because it makes the dimensions somewhat flexible. This is not to say that you shouldn't make the antennas as accurately as you can—it just means that minor errors in construction are not as important. We have chosen to make these helical antennas with a pitch of 12.5 degrees as recommended by Kraus (8). Dr. D.T. Emerson has written an excellent synopsis of the performance of real helical antennas (9). Table 1 gives the dimensions needed for these frequencies.

As you can see, the 1.2 GHz antenna is just less than 3 feet long while the 2.4 GHz antenna is just over 2.5 feet long. The diameter given in this table is the diameter of the circle formed by the center of the helical wire. Table 1 shows both the lengths of the axis of the antennas as well as the lengths of the conductors used to form the antennas.

Helical antennas need some support to hold the helix. Various things have been used by others in the past: an aluminum rod down the center of the helix with Teflon supports going out to the helical wire, varnished wooden supports, etc (10). We opted for fiberglass rods which are available at

sporting goods stores. They are replacements for sections of the external skeletons of hiking and back-packing nylon tents. The ones we obtained were about 2' long and about 11/32" in diameter. These rods are hollow and the inside hole is about the right size to be tapped for an 8-32 screw. The rods may be joined together to make greater lengths by gluing in a small piece of wooden dowel into the two ends being joined together. Alternatively, you can tap the ends to be joined together and screw in a piece of nylon threaded rod. Hobby shops carry nylon bolts (they are used in model aircraft construction) and you can make a threaded rod by cutting off the head from them. Three of these lengthened rods can be used to make the support for the antenna as shown in Figure 8. The short cross rods at the open end of the supports are made from small sections of the rods, cut to length, and glued in place. After the longitudinal rods are in place on the reflector, the short cross rods should be filed to a concave end with a rat-tail file and fitted to length by sliding them down the rods to the surface of the reflector where they should just be a snug fit. They are then glued in place (Silicone bathtub caulking is an excellent weatherproof glue) near the ends of the longitudinal rods. Place a rubber band around the assembly to hold it together until

the glue has solidified. An alternative is to drill three holes at the correct spacing for the rods in a sheet of plastic and cut out this piece to make a spacer for the end of the antenna supports. This is also shown in Figure 8. If you opt to do this, you will have to put this end spacer on after the helix has been slid onto the rods, not before.

The reflector may be circular or square. In either case, the size has a minimum value of 0.6λ ; this is either the diameter of the circular disk or one side of the square. Bigger is OK; one of us made his 1.2 GHz reflector from a 1 foot square sheet of aluminum and the 2.4 GHz one from 6" square sheet. The other author made his from near-minimum size 0.65λ diameter circular pieces of aluminum sheet. They all work. At the center of the reflector, you will need to lay out three holes for the ends of the rods. Since the ends of the rods are tapped for a screw, the holes should just be clearance holes for the particular size of screw that you use. These holes are laid out on a circle which has a diameter equal to the desired diameter of the helix minus the diameter of the wire used to make the helix minus the diameter of the support rods:

$$D = d_h - (d_w + d_r)$$

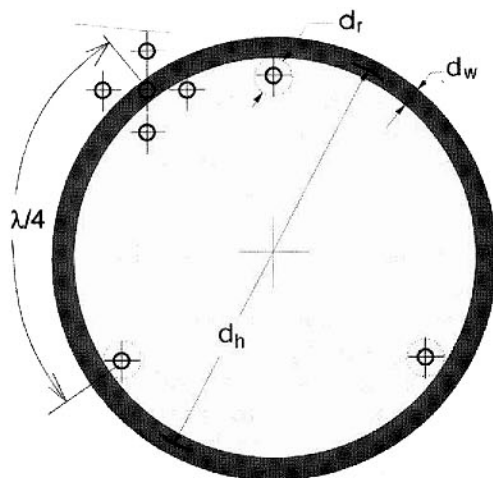


Figure 9. Helical antenna mounting template.

Frequency (GHz)	Diameter (inches)	Spacing (inches)	Total Length Conductor Needed (inches)	Total Length Along Axis (inches)
1.27	2.96	2.06	151	33.0
2.42	1.55	1.08	140	30.3

Table 1. Length of Antenna Conductors and Axis.

where the subscripts, h, w, and r, refer to the helix, wire and rods respectively. This is shown in Figure 9. Also on this reflector surface, you need to drill holes to mount the Type-N connector. These should be located so that the center pin of the connector is $\lambda/4$ around the circle along a diameter equal to the desired diameter of the helix. Since one helical loop is one wavelength long, $\lambda/4$ is one quarter of a circle.

The helix for each band was wound from 1/8" diameter soft copper refrigeration tubing. This is widely available in plumbing supply stores. The helix is made by winding it onto a form, slipping it off the form, and then mounting it onto the rod structure.

The forms needed are pieces of tubing or dowels on which we can wind the helix. The copper tubing will tend to spring back away from the form when taken off so the diameter of the form should be a little smaller than the finished diameter we want. For example, the 1.27 GHz antenna should have a finished diameter, along the center of the tubing, of 2.96". The tubing itself has a diameter of 1/8" so the inside diameter of the helix should be about 2.83". To allow for the springiness of the copper tubing when taken

off, we should make the form diameter a bit less than this – say 2.75" or so. Remember also that it is easier to put the helix on the supporting structure if it is a little smaller in diameter than it should be. That is because it is easier to unwind it slightly than it is to tighten it up if it is too loose. Similarly, for the 2.42 GHz helix, the optimum diameter of the form is about one and three-eighths inches. A suitable form for the 2.4 GHz antenna is a length of 1" PVC electrical conduit or PVC irrigation tubing. This has an outside diameter of about 1-3/8" which is about right. For the 1.2 GHz antenna, a suitable form is harder to find. There are some mailing tubes which are about the right diameter and they may be found in some of the larger stationary stores.

Start the process by marking a line down the length of the form with a good marking pen. Starting about a half inch from one end, mark off the spaces for the turns of the helix. Leave the ruler in place and mark off the increments; e.g., for the 1.27 GHz antenna, at 2.06", 4.12", 6.18", etc. Do not move the ruler and mark off successive 2.06" intervals because accumulative errors can creep in.

If your tubing is not smooth and kink free,

you will need to straighten it before winding it on the form. The easiest way to do this is to lay out the desired length (plus a little for good measure) onto a flat surface like a patio. Chuck one end of the tubing into a hand drill, have your helper or 'dear one' step on the other end and then, while keeping some tension on the tubing, turn the hand drill a few turns to and fro. Keep the hand drill low to the ground while you do this and you will be rewarded with a perfectly straight piece of copper tubing.

Next, clamp one end of the tubing to the end of the form where you started

marking the spacing. Clamp it (vise grip pliers work nicely) so that it crosses the first mark on the longitudinal line at the correct angle – about 12.5 degrees. Then, slowly wind up the tubing onto the form by rotating the form and bending the tubing to cross the longitudinal line on the form at the marks for the correct spacing. We found it easiest to do this by sitting in a chair with the form cross-wise in our lap and with the tubing lying on the floor away in front of us. As the form was rotated and the tubing wound on, it was fairly easy to make sure the spacing of the turns was done smoothly. You want to wind a right-hand helix; that is, the turns should be in the same direction as the threads on normal right-handed screw – this is important!

Make sure that the successive turns occur at the markings for the successive spaces. Try to do this as uniformly and carefully as you can. If you mess it up, you can always re-straighten the tubing and start again but you can't do this too many times as the copper will start to work harden.

Finally, with the helix completely wound onto the form, you need to flatten the first quarter turn for the matching section. Do this with a pair of pliers pinching the tubing at successive pliers jaw widths along the quarter turn plus a little extra. The pliers should be held so that the wide edge of the flattened tubing sticks out from the form. Finally, bend this flattened section so that it is at right angles to the axis of the form. The last step is to file a semi-circular notch in the end of the flat section so that it may be soldered to the side of the center conductor of the Type-N connector on the reflector. Ideally, one would want a hole drilled in the flat section to just fit over the center conductor. However, the flattened tubing is not wide enough to allow a hole of sufficient diameter to go over the center conductor. The semi-circular filed end of the flattened section should be located exactly one-quarter turn from the where the flattened section ends and the undeformed tubing starts.

Now, carefully take the wound helix off the form and slide it onto the support rods already mounted on the reflector with the flattened matching section on the end closest to the reflector. There's just one more step and then we're done.

Matching, Using the Bridge

With the antenna assembled but with the helix just temporarily mounted on the



Figure 10. Connecting the antenna bridge port to DC meter.

support rods, we are ready to do the matching. First, we need to set the VCO's to the appropriate frequencies. If you have a frequency counter that works at these frequencies, just connect the antenna port of the bridge to the counter and adjust the potentiometer until you get the right frequency (11). If you have a receiver for the frequency you want to use, tune the VCO until you hear the signal in the receiver. If you do this, you will find that, as you tune the VCO, it will go through the desired frequency very quickly and you will hear nothing more than a 'click' as you pass through the receiver frequency. Just get it as close as you can – it will drift around a bit anyway. Finally, if you have neither a counter nor a receiver, you may set the VCO frequency by adjusting the VCO tuning voltage to the value that MiniCircuits specifies for the VCO. For the JTOS-1650, this will be 3.14 V and for the JTOS-3000, it will be 2.50 V. Due to manufacturing tolerances, these voltages will just be approximate but remember that the helical antenna is very broadband so an approximately correct frequency will be good enough. There is a test point of the pc-board where you can clip a lead to your voltmeter to make this adjustment easy. Finally, if you have used a Type-N connector for the reference port, you should now put a standard termination onto this connector.

To match the antenna, you should first solder the semicircular notch in the end of the matching section to the side of the center pin of the Type-N connector it so that there is a spacing of just over 1/16" between this flattened section and the reflector. For an impedance of 84 Ohms, the theoretical ratio of the width of the flattened section to the distance from the reflector surface should be about 2:1. The spacing will therefore depend on exactly how wide your flattened section is and this will depend on how well you were able to deform the tubing when you flattened it. We got the width of the flattened section to be about 0.16" so the theoretical spacing should be about 0.08" (1/16" is just over 0.06"). Make sure that this flattened section is roughly parallel to the reflector. Then, connect the antenna port of the bridge to the antenna with your DC meter in place as shown in Figure 10. Now, take the end of the matching section and slide the whole helix away from or towards the reflector until the DC output of the bridge is a null. Your hands will affect the reading so you need to take them away to see the effect. Also, the antenna should be pointed away from

nearby objects. When you have the null, attach the helix permanently to the support rods using a few nylon tie-wraps and you're done. It isn't necessary to put a tie-wrap on each turn at each supporting rod – a few scattered along the length of the helix are all that are necessary. This whole matching process is easier to do than to describe!

You may find that the matching section has been bent so that the end of it where the helix begins is much closer to, or farther from, the reflector than the soldered end. In this case, you should unsolder it from the center pin, re-solder it with a greater or lesser (respectively) spacing from the reflector and redo the matching process. Ideally, when you're done, the whole quarter-turn matching section should be roughly parallel to the reflector surface.

Mounting the Antennas

You will want to mount these antennas on an az-el system since the beam-widths are fairly small. The antennas may be mounted by putting two U-shaped clamps on the back surface of the reflector to clamp onto the horizontal boom. These clamps are available in hardware stores as they are designed to fasten electrical conduit to walls. They are shaped like the Greek letter, Ω . They need not be located along the center of the reflector because the boom would likely be in the way of the connector. Each antenna is small enough that an off-center mounting is not a problem. Each installation will be different but be sure that you leave enough clearance so that you may mount whatever equipment you have for each band. For example, for the Phase 3D satellite, the 1.2 GHz antenna will only be used for transmitting so you will likely want to mount your 1.2 GHz final amplifier right at the connector. For 2.4 GHz, on the other hand, you will likely have a transverter with a separate low-noise amplifier and coaxial relays and there will probably not be enough room to mount the entire assembly on the back of the reflector.

Afterword

There are other uses for the bridges quite apart from matching helical antennas. The same bridge can be used to match a loop Yagi, for example. Loop Yagi's are much more narrow banded than a helical antenna so you have to be a bit more careful about adjusting the bridge to the correct frequency. However, the match is done in the same way. You adjust the antenna for a null in the DC output of the bridge. Similarly, you can use

the bridge to match parabolic antenna feeds of various kinds.

Fortunately, the VCO's used cover a fairly wide frequency range. MiniCircuits specify that the JTOS-1650 covers from 1.1 to 1.8 GHz with a 1 to 13 V change in the tuning voltage. Similarly, the JTOS-3000 is rated to cover 2.1 to 2.7 GHz for a 0.5 to 5 V tuning voltage range. Details of the voltage versus frequency for these VCO's may be found on the Minicircuits Web site. You can use the bridges at any frequency within this range. For example, Geoff, VE5ZE, has used the 1.2 GHz bridge to tune his 21 cm (1.42 GHz) H-line radio astronomy antenna helical and horn feeds by setting the bridge to this frequency and then doing the match as described above.

Assembling a pair of these bridges might make a good club project. This way, everyone in the club can use the same bridges to match their individual antennas. ■

References

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2. Ed Krome, KA9LNV, "A Compact Phase 3D Ground Station Antenna System", *QEX*, Sep 1997, pp 15-19.
3. www.minicircuits.com
4. PC boards and parts kits for the Pomona-box versions are available from SatEl, 626 Baldwin, Brentwood, CA 94513. Contact www.satelectronics.com for board and kit information. For boards only, remit \$9 (plus \$1 S&H) for one board or \$16 (plus \$1 S&H) for two boards. California residents add \$0.79 sales tax per board.
5. Sam Ulbing, N4UAU, has given a good introduction to using surface mount components in a four part series of articles in the April, May, June and July, 1999 issues of *QST*.
6. Pomona die-cast box, 2.25" x 1.38" x 1.13", part number 2417, available from Newark.
7. www.amsat.org
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10. James Miller, G3RUH, "A 16 Turn S-band Helix", FTP from the AMSAT site; [ftp.amsat.org](ftp://ftp.amsat.org). The article is located in [/amsat/articles/g3ruh/all7.zip](ftp://ftp.amsat.org/g3ruh/all7.zip). It was originally published in AMSAT-UK's *Oscar News*, Oct., 1993
11. One can be built from a kit from Almost All Digital Electronics, www.aade.com. The price for this kit, at the time this article was written was \$59.99.

Spectrum Analyzer 0...1750MHz

Part 2

Matjav Vidmar, S53MV

Editor's Note: Part 1 of this article appeared in the July/August issue of The AMSAT Journal. Note that figures 11-15 were printed in Part 1 of this article.

Sawtooth Generator and Linearization

Almost any oscilloscope can be used as a display for the described spectrum analyzer.

Although most oscilloscopes have a built-in sawtooth generator for the horizontal deflection, the generated sawtooth is usually an internal signal inside the oscilloscope and is not made available externally. A spectrum analyzer should therefore include its own sawtooth generator to drive the oscilloscope in the XY mode or synchronize the internal sawtooth generator in the oscilloscope.

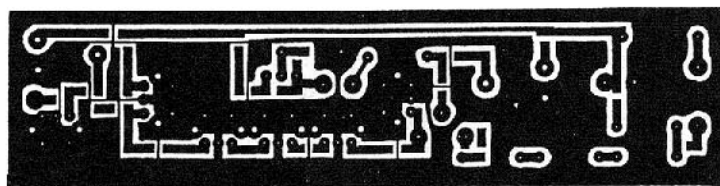
The spectrum-analyzer sawtooth generator was shown in Figure 11. The shortest sweep time is set to about 20ms or in other words corresponding to a 2ms/div sweep on the oscilloscope. The sweep time can be increased up to 20 times with the 220k log potentiometer. On the other hand, sweep times shorter than 20ms usually make no sense in a RF spectrum analyzer.

The sawtooth generator is built with a quad operational amplifier MC33074. The MC33074 performs different functions: constant-current source, sawtooth oscillator and two output amplifiers. The circuit provides two sawtooth signals for the VCO sweep and display sweep as well as trigger pulses. The supply voltage is stabilized to 30V with the integrated regulator uA723 and BD139 power transistor.

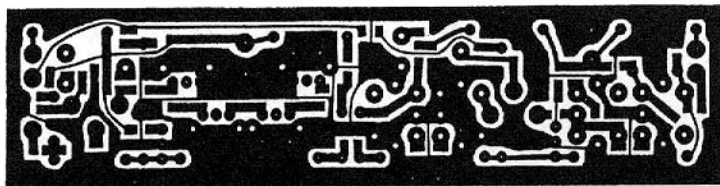
The sawtooth signal may sweep the first VCO (wide scans), the second VCO (narrow scans) or none of them in the zero-span mode. The sawtooth amplitude defines the span width. Besides the span width also the center frequencies of both VCOs have to be set to the desired values.

The described functions require several switches, selectors and potentiometers on the front panel of the spectrum analyzer. Their wiring was shown on Figure 12 together with the linearization circuit for the wideband VCO. The center frequencies of both VCOs are set with 10-turn Helipot. The span width is set with a selector in steps 1/2/5/10 etc. At 500kHz/div and narrower spans the second VCO is swept, while the frequency of the first VCO can be additionally stabilized with the STAB VCO#1 switch. Finally, the zero-span function is activated by yet another switch that removes the sawtooth and connects 47uF capacitors in parallel with the control inputs of both VCOs.

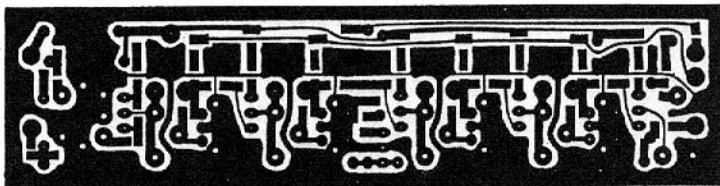
As already described in [1] and [2], the frequency response of the wideband VCO with six BB833 varactors is quite nonlinear. The tuning slope is the steepest around the center frequency of the VCO coverage, where the tuning slope reaches 120MHz/V at a tuning voltage around 7V. At lower voltages the tuning slope decays slowly to about 90MHz/V on the lower end. The tuning slope is much more nonlinear in the upper part,



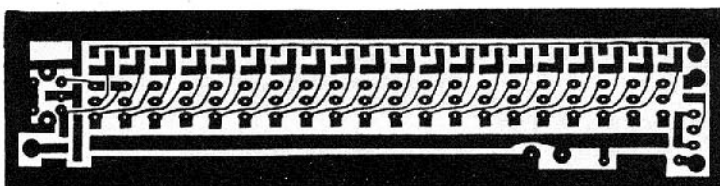
Third mixer
(30 x 120)



LC filters
(30 x 120)



Xtal filter
(30 x 120)



Log. detector
(30 x 120)

Figure 16. IF Circuit Boards..

where the tuning slope may decay below 10MHz/V at the maximum frequency.

The linearizer circuit includes two operational amplifiers. A negative feedback defines the minimum gain at an output voltage of about 7V. At lower or higher output voltages some positive feedback is switched in through resistive dividers and diodes. The positive feedback increases the gain of the amplifier to compensate for the decay of the tuning slope of the wideband VCO.

Linearization of the narrowband VCO is not required, since the latter is only swept over a small fraction of its frequency coverage. A single operational amplifier is required to drive the narrowband VCO, since the polarity of the sawtooth has to be inverted considering the frequency conversions used in the spectrum analyzer. For the same reason it makes sense to interchange the connections to the Helipot that sets the center frequency of the narrowband VCO (+30V on the beginning and ground on the end of the Helipot scale).

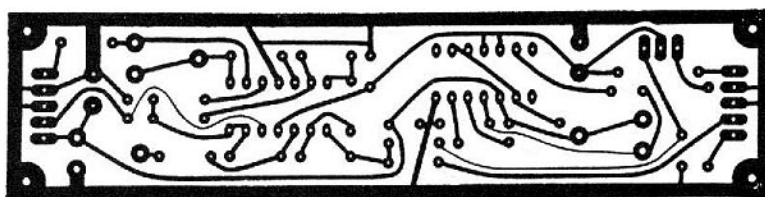
The blanking generator includes a quad voltage comparator LM339. Two comparators are used just as amplifiers for the trigger pulses to enable blanking during retrace. The other two comparators check the control voltage of the wideband VCO, turning the display off when the VCO is tuned out of range.

The LM339 comparators have open-collector outputs and the final blanking signal is obtained from a wired-or connection of three LM339 outputs.

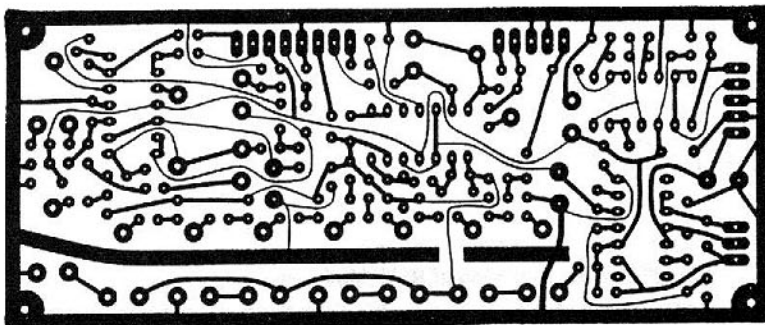
The linearizer (another MC33074) and blanking (LM339) circuits receive the same +30V supply as the sawtooth generator. The +7V reference voltage is obtained directly from the uA723 regulator on the same printed-circuit board.

Power Supply

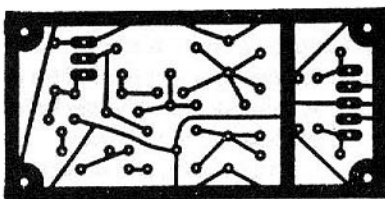
The described spectrum analyzer is designed for a nominal DC supply voltage of 12VDC, negative grounded, with reasonable tolerances (10...15V). Of course, internally the spectrum analyzer requires many different supply voltages. There are also differences in the stability requirements. Some modules require very stable and well-filtered supply voltages while others are more tolerant.



Video amp.
(30 x 120)



Sawtooth &
linearization
(50 x 120)



DC/DC converter
(30 x 60)

Figure 17. Video/Supply Circuit Boards.

Varactor diodes inside both VCOs require very stable voltages up to about +30V. Therefore the corresponding drivers require a very stable +30V supply. Considering the voltage drop in the uA723 regulator and BD139, a DC/DC converter with an output voltage of about +37V is required, was shown on Figure 13. The DC/DC converter includes a power oscillator with the transistors BC308 and BD139. Voltage spikes from the 100uH inductor are rectified by the 1N4148 diode to charge the 47uF electrolytic capacitor. When the voltage on the latter exceeds +37V, the two 18V zener diodes turn on the BC548 to stop the oscillator.

Of course, a DC/DC converter is a potential noise source to be built inside a sensitive piece of test equipment. Both input and output of the DC/DC converter are well filtered with

the 39uH and 1mH chokes as well as several electrolytic capacitors. The DC/DC converter is further built on its own printed-circuit board to be installed far away from the more sensitive circuits of the spectrum analyzer.

The power supply of the remaining circuits of the spectrum analyzer is shown on Figure 14. The input voltage +12V is first filtered with the VK200 choke and then fed to the DC/DC converter, to the video amplifier and to the 7808 regulator. The latter provides a stabilized +8V supply for most circuits of the spectrum analyzer. The 7808 regulator uses the baseplate of the spectrum analyzer as a heatsink and is installed together with the VK200, 470uF electrolytic capacitors and protection diode close to the +12V supply connector.

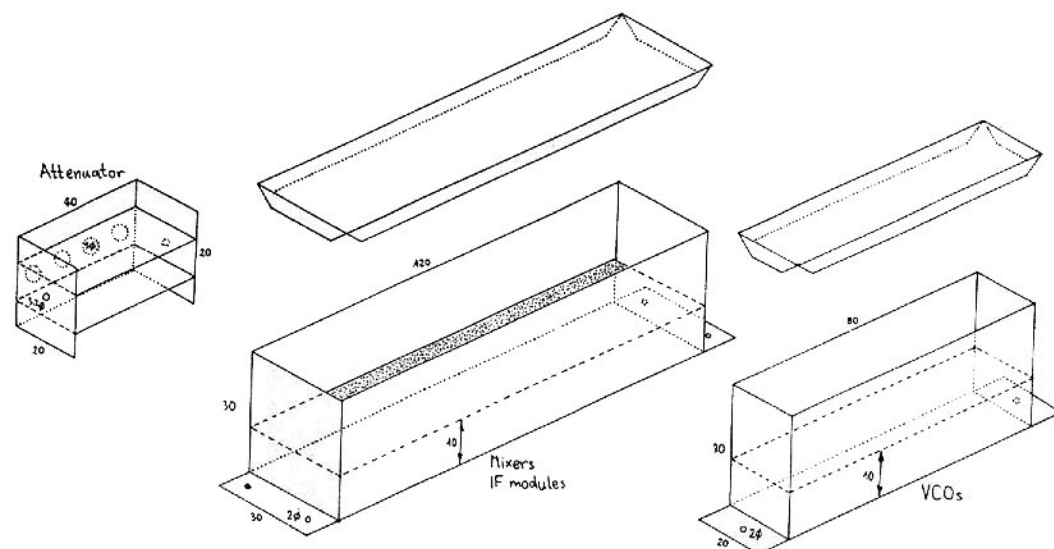


Figure 18. Shielding of RF/IF Modules.

Figure 14 also showed the IF-bandwidth switching. The latter requires a two-section, six-way selector. One section of the selector is used to switch the +8V supply voltage to different filters. The two 1N5818 Schottky diodes keep previous filters inserted while new filters are added in the IF chain. The second section of the selector sets the current in the PIN diodes that define the bandwidth of the crystal filter.

Construction Tips

A spectrum analyzer is a sensitive receiver operating over a wide frequency range. The circuits of a spectrum analyzer therefore require considerably more and better shielding when compared to conventional communication equipment. Better shielding also requires a larger number of shielded modules that contain just a few electronic components each. Besides shielding, microwave absorbers are required outside and inside some shielded enclosures.

The spectrum-analyzer modules can be roughly divided into three groups: (1) microwave modules built as microstrip circuits inside shielded boxes, (2) IF modules built on single-sided printed-circuit boards inside shielded boxes and (3) video/supply modules that do not require special shielding.

The microstrip printed-circuit boards (except the VCOs published in [1] and [2]) were shown on Figure 15. All microstrip circuits are etched on double-sided, 0.8mm-thick FR4 laminate. Only the upper side is shown on

Figure 15, since the bottom side is not etched to act as a groundplane.

Only SMD components of the size 0805 or smaller should be installed on the microstrip circuit boards. The SMD components are grounded through 2.5mm diameter holes, covered with 0.1mm-thick copper foil on the groundplane side and filled with solder before installing the SMD components. The completed microstrip boards are soldered in brass frames and covered with a shielding cover. A piece of 1cm-thick microwave absorber foam should be installed under the whole surface of the shielding cover to suppress parasitic resonances of the shielding enclosure.

The IF printed-circuit boards, shown on Figure 16, are all etched on single-sided, 0.8mm-thick FR4 laminate. SMD components should be soldered first: resistors, capacitors and semiconductors. The printed-circuit boards are designed for SMD-component sizes 0805 or 1206. Inductors, IF transformers, trimmers, BF199 transistors, BA423 diodes, crystals and electrolytic capacitors are installed as conventional "through-hole" components from the other side.

The IF printed-circuit boards are also soldered in brass frames just like the microstrip boards. Of course, the IF modules do not require any microwave absorber foam under the cover nor any special shielding on the bottom. The supply voltages go through feedthrough capacitors soldered in the narrow

sides of the brass frames while the IF cable shields are soldered directly to the brass frames.

The video/supply printed-circuit boards, shown on Figure 17, are all etched on single-sided, 1.6mm-thick FR4 laminate. All of the components are conventional types with wire leads for "through-hole" installation. The resistors and diodes are installed vertically on the sawtooth and linearization module to save some space. The video/supply modules do not require any shielding and are installed on the baseplate with four M3 screws in the corners. All connections go through simple connectors made from quality IC sockets.

The shielded enclosures of the RF/IF modules are shown on Figure 18. The input attenuator includes four miniature DPDT toggle switches installed in a sandwich between two microstrip boards. The microstrip boards are soldered to a "U"-shaped piece of 0.5mm-thick brass sheet. The four toggle switches are installed in 5mm diameter holes, while two 3.2mm diameter holes are provided for the input and output coaxial cable. The input attenuator does not require a shielding cover.

Both microwave mixers and all four IF modules are installed in a brass frame with the dimensions 120mmX30mm, while the two VCOs are installed in similar frames with the dimensions 80mmX20mm. All frames are made from 0.5mm-thick brass sheet. Covers are also made from brass, although somewhat thinner brass sheet (0.4mm or even 0.3mm) is sufficient.

Both microwave mixers include baluns made from UT-085 semi-rigid cable. The shield of the latter is first tinned for a length of about 35mm to permit expansion of the teflon dielectric. Then the shield is cut 17mm from the open end and pulled away to obtain a 1mm-wide gap. Such a prepared cable end is then soldered on the microstrip circuit board and the board is then soldered in the brass frame. The balun cable pops out of the frame for about 2mm on one side, while a longer cable (20-25mm) is available on the other side to connect the VCO.

The overall spectrum-analyzer module location is shown on Figure 19 inside an aluminum box with the following dimensions: width 220mm, depth 240mm and height 65mm. A central baseplate (1mm-thick aluminum) holds all of the

modules and divides the useful volume in two sections, each 32mm high. The top section may require a piece of microwave absorber between the second and third mixers.

While positioning the different modules on the baseplate, care should be taken that the mounting screws do not interfere with the modules on the other side. The cavity is held in place by a pair of screws on each "cold" end, so that no metal parts enter the "hot" central part of the filter. The front panel is connected to the baseplate with the TNC connector, toggle switches and Helipot, so no additional screws are necessary. On the other hand, the back panel is connected with four M3 screws in addition to the SMA connectors.

Finally, it is convenient that all display connections are brought to a single multipole connector on the back panel. The suggested 6-pole, 270-degree DIN connector is shown on Figure 20. Different displays therefore only require special cables. The same display connector also carries the +12V supply for a storage/normalizer unit or marker generator.

Alignment and Checkout

Before starting the construction of a complex piece of test equipment like a spectrum analyzer, some simpler test equipment should be available as well as enough practical experience to efficiently use the latter. Besides a conventional analog VOM-meter (digital VOM-meters are useless for tuning), a grid-dip meter, a microwave frequency counter up to at least 4GHz and a microwave power sensor should be available. Last but not least, the oscilloscope to be used as the display of the spectrum analyzer should also be available.

The construction of the spectrum analyzer should start with the most difficult part: the VCOs described in [1] and [2]. Both VCOs have to be checked for the frequency coverage and output power. In fact it makes sense to build two wideband VCOs. The best VCO is installed in the spectrum analyzer. The leftover VCO can still be used in other test equipment, like a harmonic converter that extends the coverage of a spectrum analyzer, to be described in a later article.

When both VCOs are operating correctly, the remaining modules can be built except the LC and crystal filters. The third mixer and logarithmic detector can be aligned and checked with a grid-dip meter. The operation

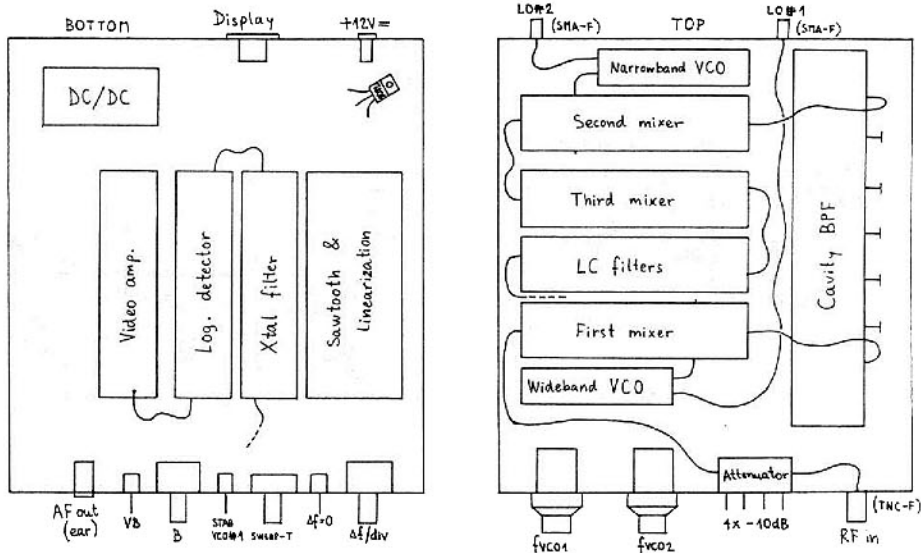


Figure 19. Spectrum-Analyzer Module Location.

of the sawtooth generator, linearization circuit and several selectors and potentiometers can be checked with the oscilloscope that will be used for display. All the trimmers in the linearization should be set to their "cold" ends.

The cavity bandpass filter is the unit that is most difficult to align without complex test equipment. The tuning screws are initially set about 1...2mm above the "hot" ends of the resonators. The narrowband VCO is set to 2.03GHz with a frequency counter while the wideband VCO is sweeping the whole frequency band. The cavity filter can then be tuned to the characteristic "DC peak" of all RF spectrum analyzers.

When the "DC peak" is found and the cavity bandpass is roughly tuned to the correct frequency, an initial checkout of the spectrum analyzer can be performed. A short antenna connected to the RF input will provide many peaks around 100MHz (FM broadcast) and 900MHz (GSM). Even better is a simple 100MHz test source built with a 100MHz ECL crystal oscillator, as shown on Figure 21.

The adjustment of the linearizer requires several signals on known frequencies. The simplest solution is a comb generator (shown on Figure 22) that provides many equally-spaced harmonics of the same fundamental frequency. The usual image on the display is rather dense lines between 700MHz and 1000MHz, while the spacing of

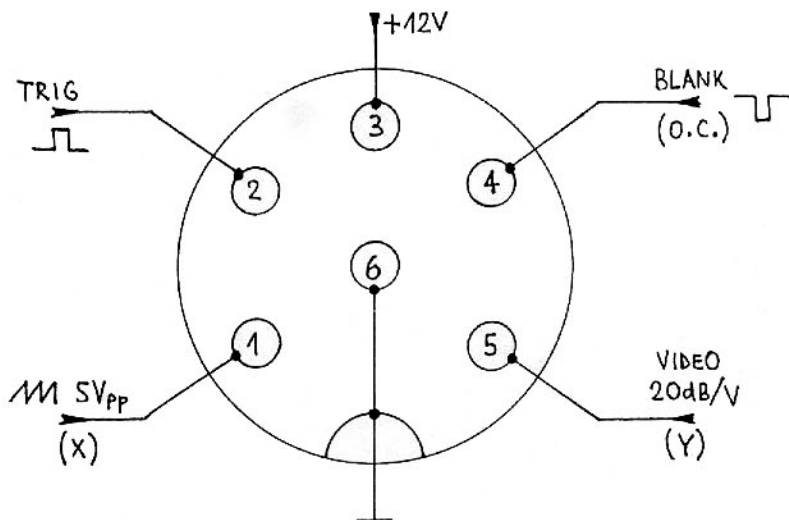


Figure 20. Display Connector.

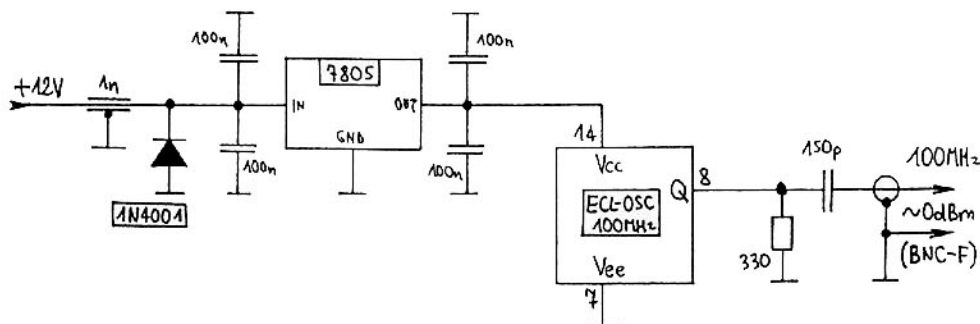


Figure 21. 100 MHz Test Source.

the lines gradually increases both towards lower frequencies and even more towards higher frequencies. The eight trimmers in the linearizer are then adjusted to obtain equally spaced lines across the whole display. If the adjustment range of the trimmers is not sufficient, other resistors in the circuit may be changed to match the response of the varactors in the wideband VCO.

When the spectrum analyzer is operating correctly with a 4MHz IF bandwidth, additional LC and crystal filters can be built. Finding suitable filter crystals is not simple. Cheap "clock" or "baudrate" crystals were found useless, since they have many spurious resonances close to the main resonant frequency. Such crystals may still provide

some useful performance in narrow SSB filters, but their response is badly distorted in wide (B=50kHz) filters for spectrum analyzers.

The only reliable crystals are those found in old 35kHz-wide filters for 50kHz FM-channel spacing. These crystal filters were usually built for a center frequency of 10.7MHz. One filter contains four different crystal pairs. Therefore two identical crystal filters have to be disassembled to obtain enough crystals for four spectrum analyzers.

Both crystal and LC filters are simply adjusted on the "DC peak", when the remaining parts of the spectrum analyzer are already operating. The alignment of LC filters

is straightforward and the desired response is obtained easily.

On the other hand, the alignment of the crystal filter is very demanding. Each filter stage has to be aligned independently while the remaining three crystals are shorted with 100ohm resistors. A symmetrical response of a single filter stage is sought with the capacitive trimmer. Next the coil is adjusted to obtain the broadest peak, of course with the current in the PIN diode turned off. This procedure has to be repeated several times for each stage, since the two adjustments interact.

After the LC and crystal filters are roughly adjusted, the two trimmers in the third mixer module can be adjusted. The mixer linearity is adjusted with a strong (around -10dBm) signal on the first mixer input. Setting the resolution bandwidth to 150kHz, some spurious responses may be visible ± 2 MHz around the desired signal. These spurious responses should be minimized by adjusting the mixer linearity. Finally, the gain of the 70MHz amplifier is set so that the front-end noise just overrides the detector noise with the 150kHz IF filter.

At the end, there are many fine adjustments to be performed. All IF filters should be aligned to the same frequency and same insertion loss. If the noise floor changes with frequency, then the symmetry of the first mixer should be improved by small drops of solder on the UT-085 balun. The remaining trimmers in the sawtooth and linearization module have to be adjusted so that the display matches the selected span width.

Of course, a number of fine adjustments are only performed after spotting problems in the practical use of the spectrum analyzer. Some adjustments, like the precise impedance matching of the wideband VCO to the first mixer, can only be performed with a tracking generator, to be described in a future article. In any case it is assumed that the builder is familiar with the theory of operation of a spectrum analyzer, since in this case most troubleshooting can be performed with the same spectrum analyzer.

References

1. Matjav Vidmar: 'Rauscharmer, breitbandiger Mikrowellen VCO', pages 26-35/4-98, *AMSAT-DL Journal*, Marburg.
2. Matjav Vidmar: 'Wideband & Low-Noise Microwave VCO', pages 210-225/4-98, *VHF-Communications*. ■

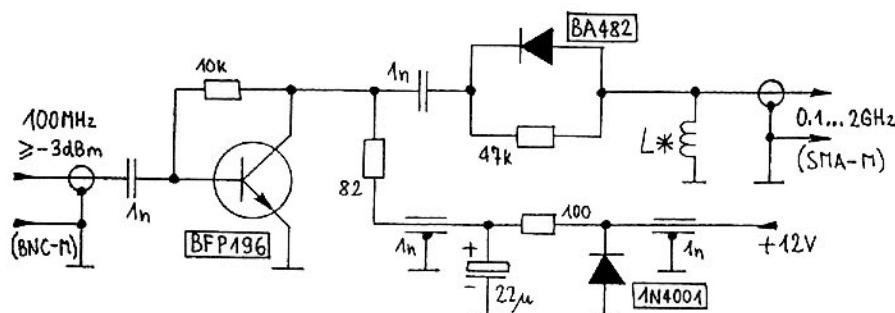


Figure 22. Comb Generator Up to 2 GHz.

2000 AMSAT Field Day Competition Results

Andy MacAllister, W5ACM

The 2000 AMSAT Field Day Competition was held in conjunction with the yearly American Radio Relay League Field Day during the fourth weekend in June. Rules for the AMSAT activity were similar to those posted by the ARRL, but with a few key exceptions. While the ARRL rules lump all satellite activity in one category, the AMSAT rules differentiate activity via the various hamsats as separate bands. The AMSAT rules also provide bonus multipliers for digital satellite downloads and uploads of Field Day greeting messages.

Activity this year was up. Every available Amateur Radio satellite had Field Day participants in pursuit of contacts. The AMSAT-rules Field Day encourages foreign stations to join the event, and several DX stations were quite active both on the analog and digital satellites.

Once again AO-10 was running extremely well for Field Day. Due to its age, and the fact that the onboard computer has been offline for over a decade, it's always a delight when conditions (orbital and solar panel illumination) make it possible for users to make solid contacts via AO-10. The deep fades on the two-meter downlink were the only problem hampering activity. Another positive surprise for the Y2K AMSAT Field Day was the operational status of KO-23. Many quality digital uploads and downloads were made via KO-23. It was off the air during the 1999 Field Day event due to power problems.

All of the top-scoring stations provided excellent documentation this year. Several spreadsheets were submitted via e-mail. In fact, almost all Field Day submissions were via e-mail this year.

Many thanks to all of you that operated in this year's event. It was a great opportunity to show other Field Day participants how easy and exciting satellites can be. It was also a chance for some competition on the birds and an occasion to test hamsat radio gear and antennas in emergency conditions.

Per the AMSAT Field Day announcement, the first-place portable station using emergency power will receive a plaque at the AMSAT meeting in Portland, Maine. Second

and third-place entries will receive certificates. The first-place home station running emergency power will also receive a certificate.

Problems? Yes. A major complaint this year revolves around the FM-voice, single-channel hamsats; AO-27 and UO-14. UO-14 has spent the majority of its time in orbit as a 9600-baud store-and-forward resource outside the ham bands for the Volunteers in Technical Assistance (VITA). When the digital system failed, it was returned to ham operation as another FM repeater in the sky. It has been fantastic, but Field Day contacts were virtually impossible due to its popularity. Only stations with luck, large antennas and plenty of power made consistent UO-14 contacts.

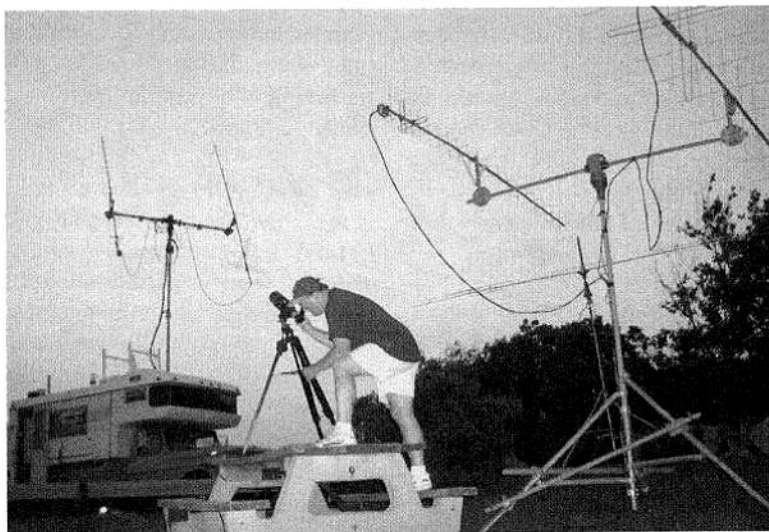
While most of the rules worked well for Field Day 2000, activity via the single-channel FM-voice satellites was a problem. There are several options regarding rule changes for this resource. We can ignore the problem and simply warn participants as we did this year, disallow Field Day contacts via these satellites, or provide a one-contact limit per station, per FM-voice satellite. Rule changes are a distinct possibility. Your input is solicited. Please send any comments to Andy MacAllister W5ACM, AMSAT VP User Services, 14714 Knights Way Drive, Houston, TX 77083-5640, USA.

Tim Cunningham, N8DEU for K4BFT: We had a great time during Field Day this year. Murphy paid us a visit several times to kill our power generator right in the middle of a few of the short satellite passes. When we switched over to the solar charged batteries for about 8 hours, our power generator problems disappeared. We made our first satellite APRS 2-way QSO with WB4APR on SO-35.

This year, we attached a pair of computer speakers to the radio with a volume control so visitors could hear what the satellite signals sounded like. It was a big hit! This years participants included John N5DF, Gregg KE4ROL, Larry WA4CAX, George K4TFJ, and John K4JCH.

Tom Mathison, WU8C for K8AYZ: Despite almost three inches of rain, and having to wear headphones just to hear anything over the pounding of the rain, we kept dry and on the air. AO-10 was in its best-ever condition. I was able to use it for most of Field Day. I enjoyed working all of you!

Albert Tencza NX2Q, for KT2K and NX2Q: Jeff, KT2K, satellite mentor to many hams, put his operating skills to good use during the contest. He also answered many questions of puzzled observers. One of the chance visitors (from Oregon) was illuminating! Bob Larkin W7PUA, author of many *QST* articles, including the article *An*



Jeff, KT2K remotely checks his antennas at NX2Q's Field Day Station.

2000 AMSAT Field Day Competition Results

Place	Call	Points	Class	Group Name
1	K4BFT	311	5A	Huntsville Amateur Radio Club
2	K8AYZ	265	3A	L'Anse Creuse Amateur Radio Club
3	NX2Q	252	2A	KT2K + NX2Q
4	AA4MD	220	1D	Tampa Children's Hospital
5	K4RS	171	2A	Fort Pierce ARC + Vero Beach ARC
6	OZ7SAT	153	2D	AMSAT-OZ
7	WA0VTU	131	2A	Pikes Peak Amateur Assoc + Mountain ARC
8	W2LV	100	4A	Sussex County Amateur Radio Club
9	W5IU	96	2A	Lockheed Martin Amateur Radio Club
10	K2SAT	88	2D	Joel Black
11	K7EFA	83	2A	Yellowstone Radio Club
11	W5XX	83	3A	Vicksburg Amateur Radio Club
13	K6YK	45	1D	John Lee
14	W5ACM	45	2A	Houston AMSAT + Houston ATV Society
15	WA5VKS	38	2D	Richard Raitt
16	XE2YVW	33	1B	Alvaro De Leon
17	N5UA	32	2A	Dr. X's Stone Knives & Bare Skins Party
18	W0WTN	12	3A	Lake Area Radio Klub
19	W7TRW	11	7A	TRW Amateur Radio Club
20	K6HAI	10	3A	North Shores Amateur Radio Club
21	WA4T	6	2A	Suncoast Amateur Radio Club
22	KK5DO	5	1D	Bruce Paige
23	W6L	4	2A	K7RR and crew
24	WB4APR	3	1A	Maryland Mobileers
25	N1SF	2	2A	N1SF Radio Club
26	KE4AZN	2	1E	Michael Kingery
27	WA3NAN	1	1D	Goddard Space Flight Center ARC
28	W5BTS	1	1D	Mahana Paige
29	K5HOU	1	5A	Clear Lake Amateur Radio Club

8-Watt, 2-Meter Brickette in the June, 2000, issue, was in New Jersey for his son's wedding. Bob's lively description of new developments in QRP DSP EME work provided a stirring start to the contest.

Friday's rare rosy sunrise should have been a signal that unusual weather was approaching, but we eventually realized that it meant that our mountain contest weather was going to be sunny, breezy and dry. We got 70 degrees by day and 60 by night. The delightful weather eased the frustration of working through the UO-14 QRM.

Dave, G1OCN uploaded a digisat message that made us aware that he was hearing many stateside stations via voice, but his signal was not being heard. This is something for stateside stations to work on. We planned to work AO-10 into the night, but sleep intruded. More next year!

Roger Snyder, K4RS: The Fort Pierce ARC Field Day was quite different this year. The area hams were invited to participate in a Hurricane Expo being held at the Civic Center on the same weekend. At first, we thought that we would move our Field Day site to the Civic Center, but we could not obtain permission to stay there during the night. We ended up returning to our regular location at the Indian River Community College.

We never seem to have enough people for Field Day, and now it appeared the shortage would be critical. Fortunately, the Vero Beach Amateur Radio Club came to the rescue by joining us in a joint effort. As a result, we were able to do some innovative things, such as a live ATV link from the Field Day site to the Hurricane Expo. Setup of the satellite station was a true test of our ability to pack up and go on a moment's notice. Normally Bill, N4XEO and I spend quite a bit of time before Field Day making preparations. Due to our busy schedules, we

were not able to do that this year. In fact, I had been out of the state and did not return until Friday. In addition, Bill and I were both rusty. Neither of us had been on the satellites since Hurricane Irene knocked us off the air last October.

Everything went smoothly at first. The only technical problem experienced was QRM from the ATV transmitter. Then a severe thunderstorm hit us. Nasty weather is common during Field Day, but I believe this was the worst I have ever seen. Heavy rain and high winds knocked over towers, destroyed antennas, and blew our tent down. The whole event was captured on video and linked to the Hurricane Expo. Talk about realism!

After the weather cleared, we picked up the pieces and put everything back together the best we could. The two-meter satellite antenna was badly damaged, but still worked. We never did get the rotors aligned properly and spent the entire event making adjustments.

I was particularly impressed with the packet operation on SO-35. The number of stations making contacts was much higher as a digipeater than as a voice repeater. I believe the last minute rule change was a very good idea. This allows stations with commonly available equipment to make satellite contacts that would not have a chance otherwise. I believe with a little publicity, that this mode will be quite popular next year.

We are looking forward to operating on Phase 3D next year and we are keeping our fingers crossed.

Bent Bagger, OZ6BL for OZ7SAT: Once again the AO-10 orbit was such that we got no QSOs whatsoever with North American stations. We managed to get a few QSOs through SO-35 before it was saturated with QRM. On the digital front we had problems with the uplink. It turned out that our AX.25 parameters were set for terrestrial use. When that was discovered and fixed it worked FB, but then there was only one pass (UO-22) left in the Field Day period. Sorry about that - we didn't mean to play it tactical!

Tom McDaniel, N0NTX for WA0VTU: Great fun! We tried to work RS-13, but the HF SSB station was a little too close and 15 Meters was open. We also tried the FM birds, but couldn't get a word in edgewise! It was

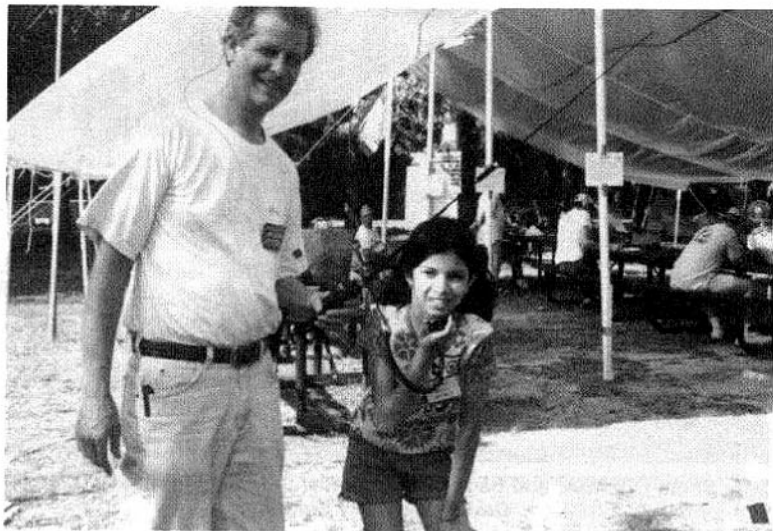
great to see KO-23 back this year. We are looking forward to Phase 3D for next year!

John Santillo, N2HMM for W2LV: The Sussex County Amateur Radio Club participated in AMSAT's Field Day 2000 using the call of W2LV 4A NNJ. The weather was cooler and dryer than in previous years making it a more pleasurable experience. The sat station also tripled as the 2M and 432 station keeping us pretty busy between passes. The Fuji birds were once again fantastic as was AO-10. We were surprised not to hear much activity on AO-10 around 0630z as AO-10 approached perigee. But, we didn't have to wait long as Europe became AOS to AO-10 and many strong downlink signals were heard. It was a real pleasure indeed working all the DX from across the pond. RS-15 was weak to us and RS-13 was loaded with QRM. The real challenge was working (?) AO-27 and UO-14. The *battle of the birds* was not for the timid. I agree that maybe one contact per FM satellite over the FD weekend will take the stress off the birds and allow the stations trying for the FD bonus points the opportunity to make a QSO. We tried to operate the digital birds as well but due to technical difficulties with our MODEM, we were unable to participate. Who knows, maybe next year if Phase 3D is functioning, it will add a whole new dimension to Field Day.

Keith Pugh, W5IU for W5IU: Doug, KG5OA and Gary, KD5DAY did the operating. Ray Hoad, WA5QGD wanted to attend, but due to illness, missed the event. However, Ray's radios and computer gear were in place for our effort. Antennas were provided by W5IU.

Joel Black, K2SAT: This was my first AMSAT Field Day and I had a really good time. My XYL got a kick out of watching me trying to make contacts with different birds as they flew overhead. One would be going below the horizon while another was rising! I need a better system for switching between analog and digital modes - I just don't know what that system might be.

SO35 with APRS was excellent. Although I copied several stations, I couldn't make my fingers work fast enough on the TH-D7A(G) to send QSLs out to everyone I heard. Bob Bruninga, WB4APR, mentioned something about how to make this easier. I'll try it next year. I have also decided to try and work the PSK birds next year along with the PACSATs. Greatest amount of my points



Bruce Paige, KK5DO and Mahana Paige, W5BTS making a handheld satellite contact.

came from the digital birds. Can't wait until FD 2001!

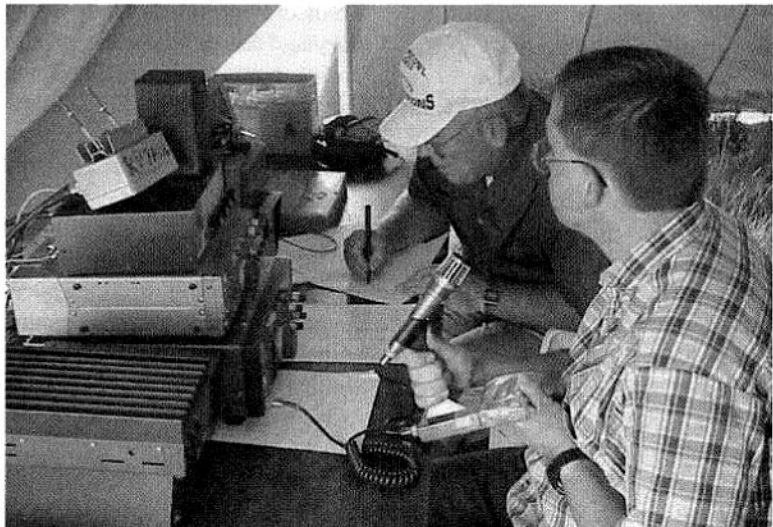
Vince Fiscus, KB7ADL for K7EFA: Thanks to all who worked the satellites this Field Day! We enjoyed working everyone.

John Lee, K6YK: Lots of activity on the FM birds! Very weak downlink on AO-10.

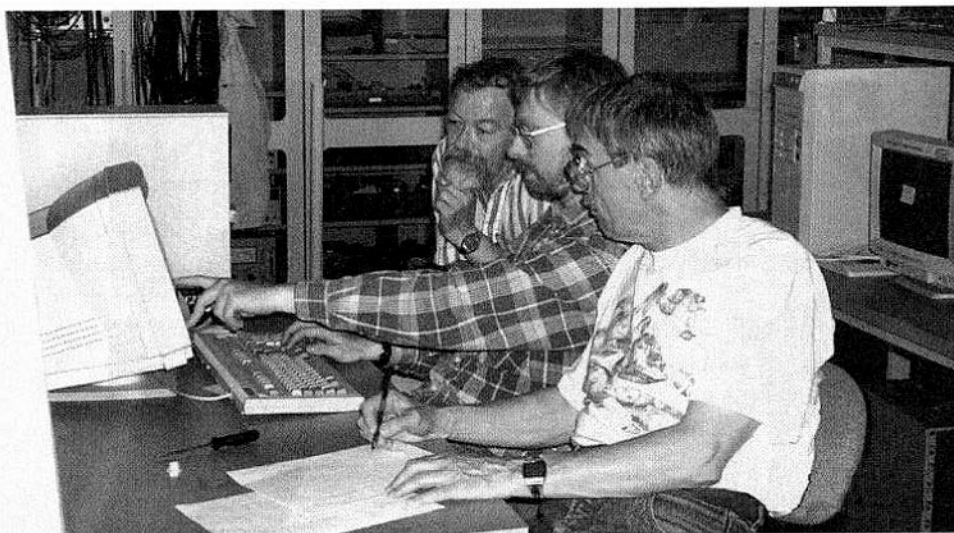
Andy MacAllister, W5ACM: The Houston AMSAT Group teamed up with the Houston Amateur Television Society (HATS) this year at a new location in Brookshire, Texas. Efforts included HF, six meters, and of course, the HAMSATS. Our experiments using the Kenwood TMD-700A for digital work yielded mixed results, but we had a lot

of fun with AO-10, SO-35, RS-13, AO-27, and even managed ONE contact via UO-14. Doug, WB5TKI and John, WA5WOD couldn't attend but their antennas and air-conditioned camper, respectively, did. Participants included Mike, WA5TWT, Ron Sparks; Tony, N5RPQ; Charlie, K5ENG and Ed, KD5ETH. It was HOT, but at least the cows kept their distance!

Dick Raitt, WA5VKS: UO-14 was too hard to work this year with the beam antennas. I had better luck with the dual-band base antenna. It was also tiring trying to work Field Day with both the ARRL and AMSAT rules, but the satellites were, as usual, a lot of fun.



Vince Fiscus, KB7ADL (r) working K7EFA OSCAR station while Bernie Miller, N7YY (l) logs.



Ib, OZ1MY; Scott, OZ1ABA; and Bent, OZ6BL ponder over the download statistics at their Danish Field Day Station.

Alvaro De Leon, XE2YVW: My homebrew version of an Arrow antenna worked fine for AO-27 and UO-14. I also used the Texas Potato Masher (K5OE design) for AO-10, FO-20, FO-29 and RS-13. Next year I will set up digital gear for Field Day.

Harold Reasoner, K5SXX for N5UA: A large 2M Cavity was required to live with broadcast TV & FM Stations within 5 miles at Cedar Hill, TX (MANY MEGAWATTS ERP). We introduced several hams to satellite operations and it was a very successful and enjoyable operation.

Joe Mayfield, KA0YOS for W0WTN: It has been a few years since ka0yos did any field day operating, but the club here in Watertown, SD (Lake Area Radio Klub) talked me into dragging out some gear and making a few "Q's". We just operated on AO-10 (we were surprised how good it was!). We had prepared to work all the analog birds, but a shortage of operators coupled with our early success kept us off the others.

James Harrison, K6OUE for W7TRW: Operators this year included K6OUE, KQ6YR, W6EKK and KF6YYV. For equipment we had and ICOM IC-820, Yaesu FT-847, Arrow 3-element Yagi, two 70-cm cross-polarized Yagis and a 10-meter wire dipole.

Dave Guimont, WB6LLO for K6HAI: We sent a few brief CQs, but most of our efforts were devoted to answering CQs to give that needed call to as many stations as we could. As usual our satellite antennas drew most of the attention to passers by. We operated in the Clairemont Recreation Center open area and had 30 or so visitors in the course of the event.

We used homebrew quadrifilar antennas, and these created a great deal of interest for radio amateur visitors.

Donald Nystrom, KA2KDP for WA4T: This is my first time to send in a Field Day Summary Sheet. I have been operating via satellites on Field Day since 1993, and this year marks my lowest QSO count. Other club members that were involved with the satellite effort this year, including Roger, AD4RX and Michael, KE4JGL. I am already planning on Field Day 2001 and hope Phase 3D is up.

Clifford Buttschardt, K7RR for W6L: We got a special event callsign this year and managed four contacts, all on AO-10 at distances greater than 20000 km from the satellite. This was primarily a demonstration station but of course got the 100-point credit for the group's ARRL score submission.

Bob Bruninga, WB4APR: The Maryland Mobileers operated from Downes Park, Maryland this year. We had excellent satellite receive demonstrations. Equipment included four Kenwood TH-D7 HTs with small hand-held three-element beams and two Alinco DJ-S41 HTs mounted inside chicken-wire corner reflectors. This allowed many operators an opportunity to receive UO-14 and AO-27 activity. We transmitted a few times with five, and then 50 Watts on the uplink, but never heard our signals. This is what we anticipated, so we were not disappointed. We also heard signals from AO-10 using an Arrow antenna. The FM-voice satellites performed as expected. No one should have expectations of success during Field Day on the single-channel, FM-voice satellites, any more than winning the lottery, unless they run enough power to

capture the satellite's receiver. Even if everyone ran one Watt, it would still be wall-to-wall QRM.

Our efforts via the digital satellites provided better results. We captured packets from 12 stations via SUNSAT and sent replies. N8DEU replied to my reply for a good countable exchange. We digipeated many packets via UO-22 (not a publically known mode), but didn't see anyone else on the air other than the large number of PACSAT users in the queue.

Grant Zehr, AA9LC for N1SF: As the local satellite "expert", the club asked me to try for a satellite QSO. Thunderstorms took out my 70-cm preamp, thus leaving us deaf on the Fuji satellites. My only other equipment at the site was for RS-13. I was lucky and made two QSOs. The QRM was terrible. Many of the stations transmitting on 15 meters were inexperienced and couldn't find themselves on the 10-meter downlink. There were also many high-power stations desensing the satellite. For us it was a chance to demonstrate satellites to other club members and a few onlookers.

The current satellites work best when everyone cooperates, but for Field Day the competition to make a contact is tough, but it IS a contest! If you can capture the bird you win!

Michael Kingery, KE4AZN: This was my first Field Day on the SATs and have only been working satellites since 1 April of this year. I have made over 125 logged contacts since I started, mainly on RS-13. I have just recently set up my station for FO-20 and 29 and have started making contacts on those birds as well. My experience is that the FM birds are difficult during normal times, and almost impossible on Field Day. If folks would relax and take turns there would be twice as many contacts made on a given pass. I might try to make one contact per pass, or just let it go. From my perspective Field Day Satellite operation was not that enjoyable. I will stick with HF for Field Day and make a Sat contact or two just for the log. I made around 292 HF contacts during field day, and had a good time.

I will save my Satellite operation for *normal* times when it is fun and more relaxed. It's really neat making a contact via a satellite and also being able to hear your own signal on the downlink. ■

Results of AMSAT Board of Directors Election

Martha Saragovitz, AMSAT Corporate Secretary has announced the results of the recent AMSAT-NA Board of Directors Election. The following number of ballots were cast for:

- Keith Baker, KB1SF - 1070
- Tom Clark, W3IW1 - 1064
- Andy MacAllister, W5ACM - 769
- Bruce Paige, KK5DO - 487
- Mike Gilchrist, KF4FDJ - 424

As a result of the election, KB1SF, W3IW1 and W5ACM will retain their seats on the Board. KK5DO is first alternate and KF4FDJ is the second alternate. They will serve until the next election.

R. Cargill Hall—Keynote Speaker at AMSAT Annual Banquet

When AMSAT members convene for their annual conference in Portland, Maine they will hear for the first time, the once top-secret details about one of the U.S. most innovative and effective intelligence collection capabilities used during the early years of the Cold War. The AMSAT-2000 meeting will feature as its banquet speaker Mr. R. Cargill Hall, Chief Historian of the National Reconnaissance Office (NRO). The NRO is one of America's key intelligence agencies and is staffed by both DoD and CIA personnel. Hall, one of the nation's leading historians in the field of aerospace technology has authored numerous classified and unclassified publications over his career with NASA and the Department of Defense. His most recent work published by the Smithsonian Institution Press is *Eye In The Sky: The Story of the CORONA Satellites*. Hall is a contributing editor to *Air And Space Smithsonian* and has contributed myriad articles to professional journals, anthologies, and encyclopedias. Among his books is *Lightning Over Bougainville: The Yamamoto Mission Reconsidered* and *The U.S. Air Force in Space*.

For further information on the AMSAT-2000 Symposium contact Carolyn Caswell, WA1MRE, walmre@amsat.org.

The Future is Now: AMSAT's Strategy Workshop

All AMSAT members are invited to participate in a workshop that will be held at the upcoming 14th AMSAT Annual Meeting and Space Symposium in Portland, Maine. The two-hour workshop will begin at 10:00 AM, Sunday, 29 October 2000 soon after the Area Coordinators' Breakfast. The workshop will solicit members' input into the development of a post-Phase 3D AMSAT strategy.

Over the past year, a team of AMSAT members has been involved in the difficult task of identifying and analyzing a variety of issues that need to be considered when developing a sound and viable strategy for AMSAT. Presently, the Strategy Team is at a point where AMSAT members' review and comment on their progress would be of enhanced value. After considering members' comments, the Strategy Team's efforts will be presented to the AMSAT Board of Directors for final review, comment, and adoption. An adopted strategy would allow AMSAT to better focus its limited financial and technical resources on what directions, and resulting projects, it considers of value to the organization.

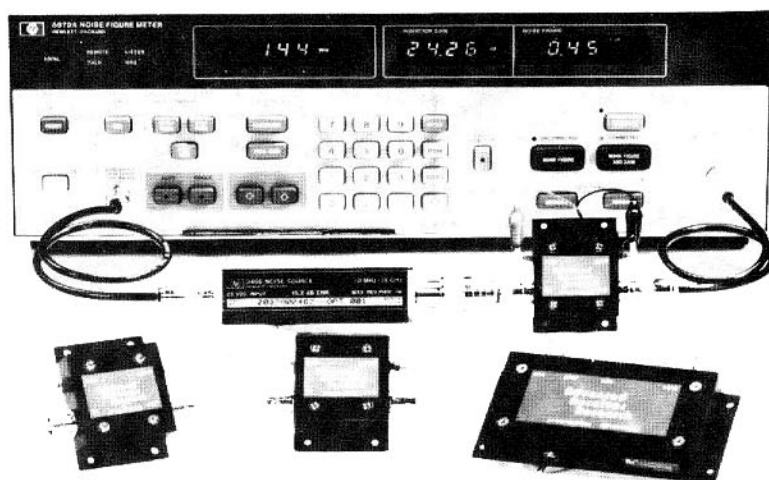
Please note that the outcome of this workshop and resulting strategy is *not to identify which particular satellite project(s) to undertake*. Rather over the next few years, what direction(s) does AMSAT need to take that would foster such projects?

At the workshop, the strategy team will present their efforts to date for members' review and comment including the presentation and discussion of several issues that affect the development and direction of an AMSAT strategy such as:

- State of AMSAT
- Available membership technical capabilities and resources to implement strategy.
- The challenge of Phase 3D and resulting dividends.
- ARISS status.
- University and other organization LEO Amateur Radio satellite construction.
- Partnering with fellow AMSAT organizations.
- Need to foster experimentation and challenges.

Upon presentation of these issues, several strategy options will be presented for review and comment by participants. The floor will also be open for members to present and/or comment on any additional strategy proposals. Certainly the ability to effectively obtain comments from the

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P50VDG	50-54	<0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	<1.5	15	0	DGFET	\$29.95
P144VDA	144-148	<1.0	15	0	DGFET	\$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	<1.8	15	0	DGFET	\$29.95
P220VDA	220-225	<1.2	15	0	DGFET	\$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95
Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	\$59.95
SP50VD	50-54	<1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	<1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	<1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	<1.2	17	-20	Bipolar	\$79.95
SP432VDG	420-450	<0.55	16	+12	GaAsFET	\$109.95

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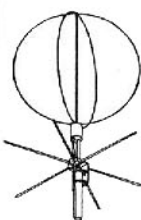
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participants of a two-hour workshop is a large and difficult task. Inasmuch, workshop participants will be allowed until 15 November 2000 to submit any additional comments and thoughts on an AMSAT strategy.

A summary of the workshop will be published in *The AMSAT Journal*. Those members who cannot attend the workshop are welcome to send their thoughts and comments on an AMSAT strategy to k5nrk@amsat.org no later than 15 October 2000. You are also welcome to provide your written or oral comments via any AMSAT member who will attend the workshop.

73 and the Strategy Team looks forward to seeing you in Portland,

Bill Burden, W1BRE, Chair
Keith Baker, KB1SF
Steve Bible, N7HPR
Ken Ermandes, N2WWD
Bdale Garbee, N3EUA
Michael Gilchrist, KF4FDJ
Robin Haighton, VE3FRH
Dan James, NN0DJ
Russ Tillman, K5NRK

Phase 3D Power Requirements by Mirek Kasal, OK2AQK

I have been asked *how much power* will be needed for Phase 3D L-band uplink. So here are my calculations:

Conditions:

- Satellite position near to apogee. Distance to the user is about 50000 km. An attenuation on the upward path will be $L_p = 188.5$ dB (on the frequency 1269 MHz).
- Sensitivity of the satellite on-board receiving system with high gain antenna was measured and calculated myself as $G/T = -9.8$ dBic/K.
- $S/N = 20$ dB for CW signal or digital signal (peak of SSB signal) in transponder passband, noise bandwidth according to SSB filter inside ground station receiver $B = 3$ kHz.
- Boltzman constant $10 \log (1.38 \cdot 10^{-23} \text{ (J/K)}) = -228.6$ (dB/Hz.K).
- No other losses have been considered (antennas disappointing, atmosphere attenuation, etc.). That means, the real situation can be worse only. But each other loss may be added.

Calculations:

- $EiRP \text{ (dBWic)} = S/N \text{ (dB)} + L_p \text{ (dB)} - G/T \text{ (dBic/K)} - 228.6 \text{ (dB/Hz.K)} + 10 \log B \text{ (Hz)}$
- $EiRP = 20.0 + 188.5 + 9.8 - 228.6 + 34.7 = 24.4$ dBWic = 275.4 Wic

Discussion:

- This EiRP can be realized by SBF antenna with the gain 15 dBic (similar to the satellite antenna) and transmitter output power 8.7 W at antenna.
- Or, by short 10 dBic helix and 28 W output power.

I believe, for good operation 3 dB reserve should be sufficient. *symbols: i = isotropic ; c = circular polarized

Phase 3D Launch Available via the Internet

Peter Guelzow, DB2OS informs us that those with a good Internet connection should be able to watch the upcoming launch of Phase 3D directly from <http://www.arianespace.com> using a Quicktime plug-in on their Browser. Meanwhile European satellite viewers have the fortune to watch (any) Ariane launch originating on the SpaceNight of the German BR3 TV channel (Bavaria). The schedule is on <http://www.spacenight.de/>

SAUDISAT-1A, 1B, and TIUNGSAT-1 Information

Dr. Turki Al Saud, Director, Space Research Institute, Saudi Arabia has announced via amsat-bb that the first Amateur Radio satellites from The Kingdom of Saudi Arabia are presently being built by the Space Research Institute at the King Abdulaziz City for Science and Technology in Riyadh. After a delay in August, the launch is tentatively set for September 2000. These satellites will be capable of 9600 digital store and forward operation (Pacsat Broadcast Protocol compatible) as well as FM bent pipe mode. Uplinks are in the VHF band and will be announced after commissioning with the following downlink frequencies

- SAUDISAT-1A: 435.075 MHz
- SAUDISAT-1B: 436.775 MHz

Al Saud reports that Amateur Radio is in its infancy in Saudi Arabia and with these satellites they hope not only to add satellites to the space resources available to hams world wide, but to increase the awareness of the value of Amateur Radio in the Kingdom.

Meanwhile, Sangat Singh, 9M2SS reports that the first Malaysian Amateur Satellite, TIUNGSAT-1, is also to be launched on the same vehicle DNEPR-1 as SAUDISAT-1A and SAUDISAT-1B. The launch will occur from the Baikonur Cosmodrome, Khazakstan.

The details of Tiungsat-1 (Named by Malaysian Prime Minister after the Malaysian bird 'Myna') are as follows:

- Dimension: 690 x 390 x 360 mm
- Mass: 50 kg. (platform: 35 kg; payload 15 kg.)
- Solar Array Power: 35 W (max) GaAs solar cells
- Payload: Multi-Spectral Earth Imaging System (MSEIS), Meteorological Earth Imaging system (MEIS), Digital Store and Forward
- Orbit Altitude: 645.1 km (apogee) / 639.7 km (perigee)
- Inclination: 65 - 67 degrees
- Eccentricity: 0.004
- Data Transmission: FM and FSK
- Data Rate: 9.6 kbps, 38.4 kbps and 76.8 kbps
- Uplinks Frequencies: 144.460, 145.850, 145.860 MHz.
- Downlink Frequencies: 437.300, 437.325, 437.350, 437.375 MHz.

- Antennas: 4 monopoles, gain 0dBi, Radiation pattern omni-directional

TIUNGSAT-1 is the result of a technology transfer collaboration between the Astronautic Technology (M) Sdn. Bhd. (ATSB) and Surrey Satellite Technology Ltd. (SSTL)

ARISS Ham Gear Cleared for Takeoff

The way has been cleared for the Amateur Radio gear destined for use aboard the International Space Station to be launched into space. The initial amateur gear is scheduled to go up to the ISS on mission STS-106 aboard the shuttle Atlantis on September 8. As part of the multinational Amateur Radio on the International Space Station project, the gear will be stowed aboard the ISS for use by the Expedition 1 crew, set to come aboard in late October.

"We have been working for years to bring the first ISS hardware to fruition," ARISS Administrative Chairman Frank Bauer, KA3HDO, said this week. "It looks like the final issues that have held us back are now over, and we are moving ahead toward the launch of the initial hardware on STS-106."

Bauer said three events over the past couple of weeks were key to moving the ARISS project forward. The first was the launch and docking of the Russian-built Zvezda Service Module that eventually will house the ARISS gear. In addition, Bauer said, a series of RF, power-up and other tests on the amateur equipment were successfully completed in Russia, thanks to Lou McFadin, W5DID, of ARISS and AMSAT and Carolyn Conley, KD5JSO, of NASA. He said NASA also signed off on the required flight safety package, giving the go-ahead to release the amateur hardware for flight aboard the upcoming shuttle mission.

The Expedition 1 crew will consist of three amateurs: US astronaut Bill Shepherd, KD5GSL, and Russian Cosmonauts Sergei Krikalev, U5MIR, and the recently licensed Yuri Gaidzenko, whose call sign was not available.

To be available to the first crew, the ARISS initial station gear will be installed temporarily aboard the ISS Functional Cargo Block. It will use an existing antenna that's being adapted to support FM voice and packet on 2 meters but not on 70 cm. Eventually, the ARISS gear will find a more-permanent home aboard the Zvezda Service Module. A Russian call sign, RZ3DZR, has been issued for the ISS ham radio station.

The ARRL and AMSAT have been providing leadership and consulting services for ARISS. ARRL Field and Educational Services Manager Rosalie White, K1STO—a member of the Space Amateur Radio Experiment Working Group—says this is an exciting moment for the

Satellite Orbital Elements

by Ray Hoad, W5QGD

Satellite	AO-10	UO-14	FO-20	RS-12/13	RS-15	FO-29	AO-27	UO-11
Catalog Number	14129	20437	20480	21089	23439	24278	22825	14781
Epoch Time	244.30493153	244.48908037	243.83508056	244.21946130	242.84791931	243.74956273	243.92588468	244.89147560
Element Set	684	551	276	271	496	371	901	321
Inclination	26.7654	98.3964	99.0648	82.9242	64.8157	98.5804	98.3986	97.9891
RA of Node	313.6331	308.9581	0.298	130.1269	61.3616	141.7885	298.149	206.663
Eccentricity	0.6013318	0.0010616	0.0539697	0.0027934	0.0167354	0.0351901	0.0009347	0.0009648
Arg of Perigee	80.7845	354.4127	246.3357	278.07	276.5381	34.0919	46.7941	215.2823
Mean Anomaly	338.6411	5.758	108.0222	81.7286	81.6505	328.2293	313.402	144.7749
Mean Motion	2.0586917	14.30500237	12.83277239	13.74214459	11.27537462	13.52733791	14.28208918	14.72492508
Decay Rate	-0.00000011	0.00000016	0.00000006	0.00000074	-0.00000042	-0.00000009	0.00000161	0.00001291
Epoch Rev	12947	55363	49485	47998	23381	19937	36114	88344
Satellite	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23	IO-26	KO-25
Catalog Number	20439	20440	20441	20442	21575	22077	22826	22828
Epoch Time	244.25612856	243.27472979	243.94358951	244.64699294	243.96154714	244.88776919	243.65441168	244.16047050
Element Set	349	359	438	349	145	940	844	811
Inclination	98.442	98.452	98.4499	98.4538	98.1475	66.0838	98.4036	98.3963
RA of Node	315.5009	316.6487	316.9597	319.289	267.5816	211.8469	298.552	299.2137
Eccentricity	0.001163	0.0011369	0.001191	0.0012638	0.0007663	0.0012712	0.0009991	0.0010908
Arg of Perigee	1.4077	3.1175	3.2759	355.299	343.7643	299.2869	44.7333	25.1043
Mean Anomaly	358.7137	357.0072	356.8499	4.8697	16.3297	60.6878	315.4652	335.063
Mean Motion	14.30581712	14.30771801	14.3067908	14.308183	14.37805576	12.86349311	14.28359516	14.28765342
Decay Rate	0.0000014	0.00000164	0.0000017	0.0000024	0.00000273	-0.00000037	0.00000133	0.00000194
Epoch Rev	55362	55353	55362	55376	47866	37845	36113	32937
Satellite	TO-31	GO-32	SO-33	PO-34	SO-35	UO-36	AO-37	OO-38
Catalog Number	25396	25397	25509	25520	25636	25693	26065	26063
Epoch Time	243.93598256	243.95295751	243.26794933	243.79353591	243.85556390	243.97922330	243.23111599	243.63680696
Element Set	382	330	219	214	226	334	76	94
Inclination	98.7163	98.719	31.4431	28.4636	96.4497	64.5588	100.2093	100.2075
RA of Node	318.6434	318.3945	198.8527	74.7403	69.9294	242.1309	118.8365	119.3004
Eccentricity	0.0002298	0.0000293	0.0364694	0.0006872	0.0151726	0.0048881	0.003747	0.0037072
Arg of Perigee	201.2371	181.3528	358.9729	349.2238	305.5201	286.099	303.9716	302.3419
Mean Anomaly	158.872	178.765	1.0128	10.8231	53.1921	73.4732	55.7911	57.42
Mean Motion	14.22740591	14.22449396	14.25013621	15.06302219	14.41409241	14.73544866	14.34294273	14.34367818
Decay Rate	-0.00000044	-0.00000044	0.00001232	0.00002205	0.00000258	0.0000058	0.00000315	0.00000173
Epoch Rev	11128	11129	9640	10114	7984	7332	3097	3104
Satellite	WO-39	UNK3	UNK4	OCS	MIR	ISS	Phase 3D - 1	Phase 3D - 600
Catalog Number	26061	26093	26094	26062	16609	25544	99001	99003
Epoch Time	241.84453171	243.62730786	243.10770718	244.51934681	244.46347568	244.42329861	214.97200000	7.00000000
Element Set	96	101	70	255	990	20	1	3
Inclination	100.206	100.2048	100.2043	100.2277	51.6474	51.5773	6.5000	63.5000
RA of Node	117.2988	119.377	118.6606	124.4405	235.5978	115.755	109.0000	327.0000
Eccentricity	0.0036304	0.003732	0.0037597	0.0028642	0.0012407	0.0009666	0.7340000	0.7830000
Arg of Perigee	307.5704	304.1377	305.9119	294.5266	357.5487	4.2883	176.0000	352.0000
Mean Anomaly	52.2179	55.628	53.8588	65.3583	2.5428	344.8841	0.0000	0.0000
Mean Motion	14.34852934	14.35355666	14.34842265	14.53980836	15.73106572	15.69143813	2.04300000	1.50000000
Decay Rate	0.0000068	0.00001267	0.00000719	0.00039974	0.00046493	0.0002901	0.00000000	0.00000000
Epoch Rev	3079	2887	2827	3137	83095	10173	9	600

project, which has one goal of letting students on Earth communicate with the ISS inhabitants via Amateur Radio.

"All of the hard work from the many volunteers is starting to pay off," she said. "We have so many people to thank—all of the AMSAT volunteers, ARRL people, the NASA folks—so many of whom are hams. But seeing the youth of the United States and other countries benefit is our reward."

Bauer says the astronauts and cosmonauts plan to take some time off for educational outreach contacts with schools, even during the busy years of ISS construction that lie ahead. Bauer says access to Amateur Radio also is considered a morale booster for ISS crew members who will be in space many weeks at a time.

"As the International Space Station takes its place in the heavens," Bauer said, the Amateur Radio community is prepared to do its part by helping to enrich the experience." *Via ARRL News Service.*

AMSAT-UK Colloquium A Success by Richard Limebear, G3RWL

AMSAT-UK's Y2K Colloquium was held over the last weekend in July. Seventy-one participants attended from 14 countries and were

addressed by 22 different speakers on a variety of subjects from the simple to the deeply complex. Other features of the weekend included a firing of SSTL's rocket thruster, a demonstration of 2400 MHz reception from SSTL's minisat UO-36, an IARU Forum, and guided tours around Surrey's impressive ground command facility.

No doubt the IARU Satellite Coordinator will issue a full report of the Forum in due course. Following Graham Ratcliff, VK5AGR relinquishing the position of Satellite Frequency Coordinator, the Forum was asked for nominations for his successor and strongly recommended Peleg Lapid, 4X1GP, for this position.

This year's event was planned to have a lot about Phase 3D - we weren't disappointed. Apart from several items of hardware being discussed, we were also told that the new provisional date for Phase 3D's flight into orbit was 31 October 2000. The launch campaign should start on 11 September; fingers crossed.

But there were other talks as well: The one about Satellites-on-a-Chip (including solid-fueled thrusters) met with such interest and acclamation that the speaker (on UoS academic staff) has promised us an article for *OSCAR News*.

The leader of the University of Bristol's Project HAND told us about their progress. He also happens to be the President of the British Interplanetary Society so we had a separate talk about that as well. (I was amazed that only two people at the Colloquium belonged to this organization.)

Each of the Beginners' sessions (General, Analog, Digital) had between 15 and 20 attendees; organization of these was delegated to G7HIA and W2RS. Of particular interest were the live demonstrations via UO-14 and AO-27 that netted almost twenty contacts with about eight countries using just an HT and an Arrow antenna. There was especial interest in the transatlantic contacts. QSL via G3RWL.

We finished up with a talk about SSTL's future plans ... including lunar and interplanetary missions.

Next year's event will probably take place over the same weekend, the last one in July (27 to 29 July) 2001. With P3D hopefully in orbit by then we have high hopes that attendance (and membership) will pick up. The following suggestions for 2001 have been made: Antenna Test facility (NB NOT a full antenna range); Beginners' sessions, *Show and Tell* presentations. A call for papers will probably issue about November 2000. ■

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